CONSTRUCTION ELECTRICIAN'S MATE

3 & 2

PREPARED BY

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSES

NAVPERS 10636-A

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PREFACE

This book is written for men of the Navy and of the Naval Reserve who are studying for advancement to the rates of Construction Electrician's Mate 3 or 2. Combined with the necessary practical experience and a thorough study of the Basic Navy Training Courses, the information in this training course will prepare the reader for advancement in rating examinations.

The first chapter provides the reader with general information concerning his work, the proper way to use the book to his best advantage, and a reference reading list of other Navy Training Manuals that will prove of benefit to him. Subsequent chapters are divided into three main parts. The first part deals with batteries, motors, and generators. The second part covers the distribution of electricity for light and power. And the third part covers telephone communications.

As one of the NAVY TRAINING COURSES, this book was prepared by the Navy Training Publications Center of the Bureau of Naval Personnel, with technical assistance from the Bureau of Yards and Docks.

CREDITS

All illustrations published in Construction Electrician's Mate 3 & 2 are official U. S. Navy photographs unless designated below:

Source	*Figure*
Crescent Insulated Wire & Cable Co.	6, 7, 12, 14, 15
The Okonite Co.	8, 9, 10, 11, 16
McGraw Hill Book Co.	20, 21, 22, 23, 24, 25, 26, 30, 31, 230, 232, 233, 268, 292
General Electric Co.	65, 87, 107
Century Electric Co.	86
American Technical Society	116, 133, 134
American Schools	132, 135, 136, 137, 138, 149, 167, 168, 172, 229, 274
Fairbanks-Morse	146, 148, 150, 151, 152
Bruce Publishing Co.	204
D. Van Nostrand Co.	218, 280
Stean-Steel Division, Great Lakes Steel Corp.	287

STUDY GUIDE

The table below indicates which chapters of this book apply to your rating. To use the table, follow these rules:

1. Select the column which applies to your rating. If you are in the Regular Navy you will use the column headed CE, which is the general service rating. If you are a member of the Naval Reserve you will use the column headed by your particular emergency service rating—CEL, CEG, or CEP.
2. Observe which chapters have been marked in your RATING column with the number of the RATE to which you are seeking advancement.
3. Study those particular chapters. They include information which will assist you in meeting the qualifications for your rating. (See appendix I of this book for a complete list of qualifications for advancement in rating.) In order to gain a well-rounded view of the duties of the general service rating, it is recommended that you read the other chapters of this book even though they do not pertain directly to your rating.
4. Here is an example: If you are a member of the Naval Reserve studying for advancement in rating to Construction Electrician's Mate G3, you will select the column headed CEG. Following this column down you will observe that you must study chapters 1, 2, 3, 4, 6, 7, 11, 15.

Chapter	CE	CEG	CEP	CEL
1	3, 2	3, 2	3, 2	3, 2
2	3, 2	3, 2	3, 2	3, 2
3	3, 2	3, 2		3, 2
4	3, 2	3, 2	3, 2	3, 2
5	2	2	2	
6	3, 2	3, 2	3, 2	3, 2
7	3, 2	3, 2	3, 2	3, 2
8			2	
9	3, 2		3, 2	
*10	2		2	
11	3, 2	3, 2	3, 2	
12	3, 2			3, 2
13	3, 2			3, 2
14	2			3, 2
15	3, 2	3, 2	3, 2	3, 2

*—All rates will read the section entitled ELECTRIC SHOCK

BOOKS FOR ADDITIONAL STUDY

General Training Course for Non-Rated Men, NavPers 10601

General Training Course for Petty Officers, Part I, NavPers 10602-A

Mathematics, Vol. 1 and Vol. 2, NavPers 10069, 10070

Electricity, NavPers 10622

Use of Tools, NavPers 10623

Use of Blueprints, NavPers 10621

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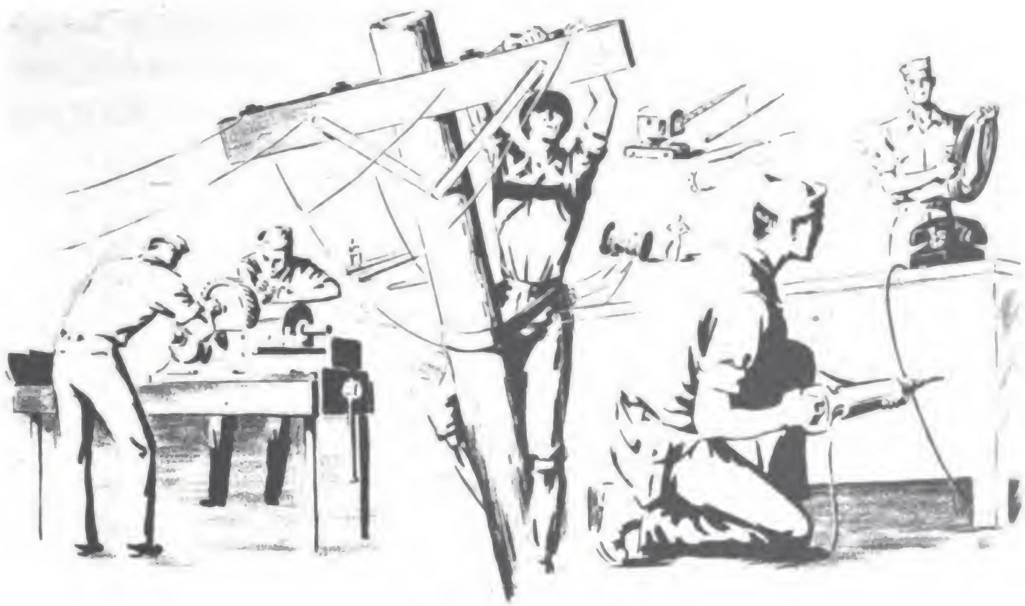
CONSTRUCTION ELECTRICIAN'S MATE

3 & 2



CHAPTER 1

GETTING ACQUAINTED

"CAN DO"

Just two words, "can do," but it's the story of the Seabees in a nutshell. In World War II it was "can do" that built airstrips, carved advanced bases out of jungle, and unloaded ships—in record time. Empty oil drums became sewage pipe, and coconut trees doubled as telephone poles. Electric generating stations were built—using enemy equipment.

What does all this mean to you? Plenty! Whether you're a Constructionman striking for CE 3, or a Construction Electrician's Mate reaching for his second stripe, you are going to need a lot of "can do." It means READING books, ASKING questions, and just plain DOING. You will find the first step of the ladder the hardest to reach. How far you climb depends on YOU.

MEET YOUR BOOK

This manual is only a stepping stone to your next rate. When you finish don't start sewing on that stripe. It's not as easy as that. You can't climb a telephone pole by just READING how it's done. You need actual PRACTICE, too.

What does this manual offer you? Well, among other things, it gives you the "language" of the CE and describes his work and equipment. You may not know how to climb that tele-

Figure 1.—You can't climb a pole by just reading.

phone pole when you've read this book, but you will know the correct side to start on. And when the chief sends you for a pair of "climbers" you won't bring back a monkey wrench.

What Your Book Covers

You will find the manual divided into three sections—

The first part of the manual introduces you to batteries, motors, and generators. Here you will find information on the installation, repair, and maintenance of dry cell and storage batteries. You will learn about the different types of motors, the methods of controlling them, and where you fit into the

picture on their repair and upkeep. Advance-base generating equipment is described so as to help you stand a generator watch and be familiar with generating station duties.

The second part of the manual covers the distribution of electricity for light and power. You will study the different types of electrical systems. You will find out why transformers are used, how they are connected, and how to install them. You will be shown the methods of erecting poles, attaching crossarms, and stringing wire.

The last section of the manual deals with telephone communications. It describes how the telephone works, and methods of its installation. You will learn about the need for switchboards, where they are used, and how to operate them. Last, but not least, you will learn about telephone-line construction.

Using Your Book

The subjects, or parts of the book, which you will study depend on the rating you hold. Your Navy has divided the rating of Construction Electrician's Mate into two groups—the GENERAL SERVICE RATING and the EMERGENCY SERVICE RATING. If you are a Regular Navy man on active peacetime duty,

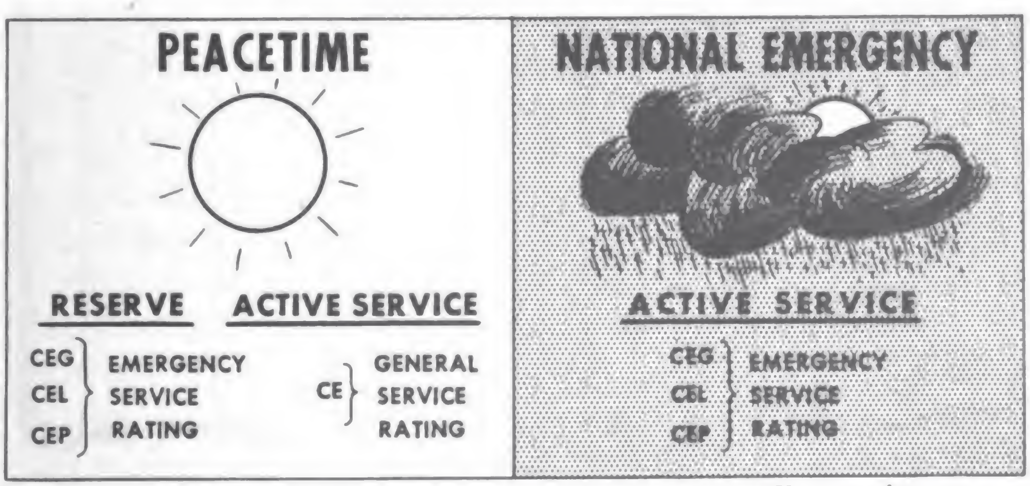


Figure 2.—Emergency and general service ratings.

you belong in the general service group. If you are attached to the Reserves on inactive duty you will find your berth in the emergency service group.

In the general service group your rating is designated as CE or Construction Electrician's Mate. In the emergency service group your rating may either be CEG, CEP, or CEL. The letters "G," "P," and "L" attached to the CE indicate the type of electrical work you specialize in. CEG is a general electrician; CEP a power linesman, and CEL a communications linesman.

In times of national emergency, all ratings fall under the emergency group. If you are a CE in the Regular Navy, your rating will be changed to either CEG, CEL, or CEP. The one you get depends on your past work. If a Reserve, however, you will keep the rating you have.

At the back of this manual you will find a chart labeled, "Qualifications for Advancement in Rating." It simply tells the things you've got to know to climb that ladder. These "quals" are separated into PRACTICAL FACTORS and EXAMINATION SUBJECTS. You pass the practical quals by showing that you can actually DO them. You pass the examination quals when you prove your worth in a WRITTEN test.

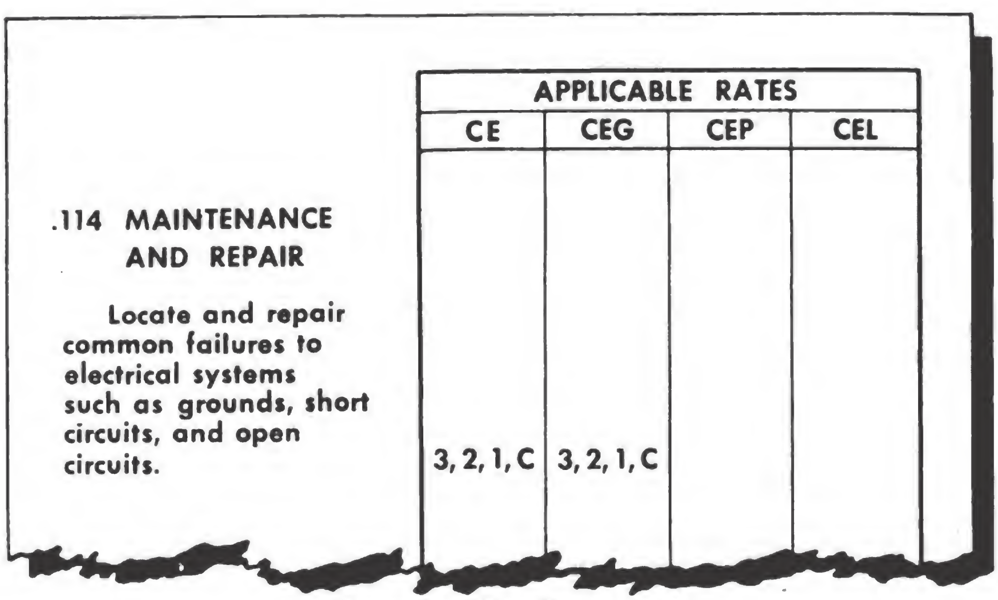


Figure 3.—The Quals chart.

You should know how to use the quals chart because this manual is based upon it. Figure 3 shows a part of that chart.

Where do you fit in? That's easy. First, find the column that applies to your rating. If you're Regular Navy, look in

the CE column. If you are Reserve, look in the CEG, CEP, or CEL column.

Second, find out what quals you have to study. If you are striking for third, check for the quals which have the number "3" listed in your column. If you are qualifying for second, check for the number "2." Look at figure 3 again. The quals shown must be studied by the CE3 striker, the CE3, the CEG3 striker, and the CEG3. It does not have to be studied by the CEP or CEL ratings.

The Helpers

In this manual you will find two "helpers." They are at the end of each chapter. One is a SUMMARY and the other a TEST. The summary helps you by grouping the important points of the chapter together and calling them to your attention. Answering the questions helps you by testing how well you've read the chapter. If you can't answer a question, it means you have missed a point. DON'T GO ON TO THE NEXT CHAPTER UNTIL YOU HAVE ANSWERED ALL OF THE QUESTIONS.

OLD AND NEW FRIENDS

Chances are you know all about the Basic Navy Training Courses. If you don't, this is a good time to become acquainted with them.

The Basic Navy Training Courses were written to help you build a strong foundation for further advancement in your rating. You can never expect to gain a rating if your foundation of basic facts is weak. This applies both to basic facts about your Navy and to your specific job.

Basic facts about the Navy come under the heading of MILITARY REQUIREMENTS. What makes the Navy tick and the part you play in it are important to you. You were introduced to basic military requirements when you read *General Training Course for Non-Rated Men*, NavPers 10601. As a petty officer your responsibilities increase. That means learning more if you want to get the job and hold it. To learn the basic facts about your work as a Petty Officer, read *General Training Course for Petty Officers*. Like NavPers 10601, it can be obtained from your educational office.

Learning to be a Construction Electrician's Mate will be easy if you are familiar with the fundamentals of that rating. These fundamentals, or basic facts, are part of the PROFESSIONAL REQUIREMENTS of the Navy. You must know them before you start this manual. You will find them in the basic training courses which are discussed below.

Mathematics

As an electrician you will be called upon to use your brain as well as your brawn. The brain work means using mathematics to figure out electrical problems. If your knowledge of math is rusty, apply a little lubrication by reading the basic training course, *Mathematics*, NavPers 10620.

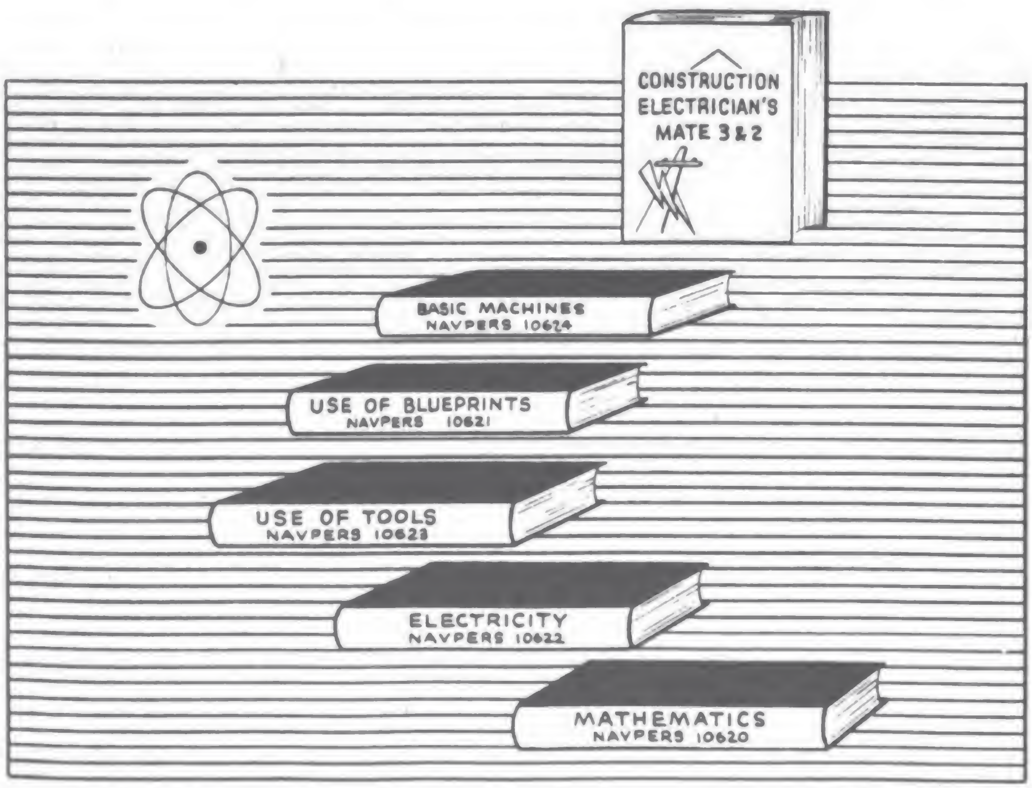


Figure 4.—Stepping stones.

Basic Electricity

If you are striking for a third class rate, you must know the basic theory of electricity. You should be familiar with the electron theory and be able to solve direct current problems

involving Ohm's Law and Kirchhoff's Law. Checking and testing circuits is also a part of your job. That means knowing how to use a voltmeter, ammeter, and ohmmeter properly.

If you are preparing for a second class rate, you have to meet all the qualifications for third, PLUS being able to solve simple alternating current problems.

If you are a CEL striker or qualifying for CEL2, you have an added job. You must know the theory and practical phases of inductance, frequency, capacitance, wave length, and vacuum tubes as applied to communications.

Where do you find all these subjects? Easy as 10622. They are fully covered in the Basic Navy Training Course, *Electricity*, NavPers 10622.

Tools

Everyone knows what an ordinary pair of pliers looks like. But did you know that there are more than seven members of the plier family? Needle-nose, side cutters, and flat-jaw are but a few of the types of pliers you will work with. Each is designed to do a certain job. You should be familiar with them, and all the other common hand tools used in electrical work. Power-driven tools, such as grinders and drills, are also on your "must know" list.

Use of Tools, NavPers 10623 is the book to read if your knowledge of tools is limited. In it you will find a description of all the common hand and power tools, where they are used, and the right way to treat them. This is basic information which you MUST know.

Blueprints

Have you ever been lost without a map? Unless you're stubborn you ask the way to your destination. The reply follows the same old pattern of, "turn left at the next cross-road, then right when you come to a big tree, etc., etc." Trying to follow word-of-mouth directions usually leaves you worse off than you were. But stop in a gas station and get a map, and your worries are over. From a map you can find your present position and the place where you want to end up. All you have to do is follow the lines which connect the two points.

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If you're lost when it comes to repairing a piece of electrical equipment, you can find your way by using an electrical blueprint. The blueprint is the MAP of the electrician. Like a map it has lines going from one point to another. In this case, how-

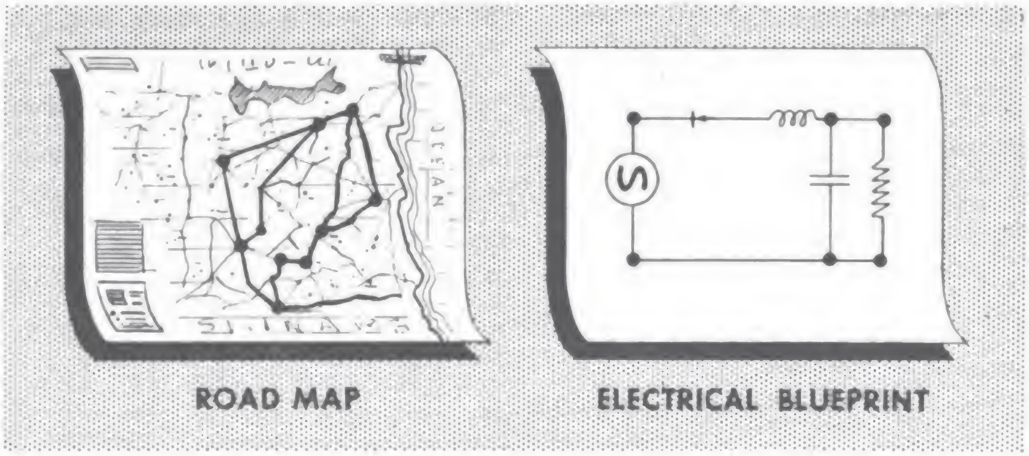


Figure 5.—If you're lost try a map.

ever, the lines represent wires carrying current, instead of roads carrying traffic.

Knowing how to read and work from blueprints is important to you. Reading *Use of Blueprints*, NavPers 10621, will help you reach those goals. This basic training course gives you the common electrical symbols used in electrical blueprints. It also tells you the difference between wiring diagrams and schematics, and how to read them.

Basic Machines

A machine is any device that helps you do work. Levers, block and tackle, inclined planes, and gears are a few examples of basic machines. You may be wondering what the basic machine has to do with your work as an electrician. The answer is—PLENTY!

As a GENERAL electrician you may be called upon to help set up a generating station. If you have ever seen a 75-kilowatt Diesel generator, you know they are big babies. Moving and setting them in place requires help. You get this help from the block and tackle, lever, or any other basic machine that you can put to use.

Whether you're a TELEPHONE or POWER linesman, you will be

constantly using all kinds of basic machines. Telephone poles are easily moved and erected—if you use basic machines. That goes for stringing wires, too. They must be raised to a certain height on the pole. You can't do it alone, but with a block and tackle it's a cinch.

You can get your basic machine information from the Navy Training Course, *Basic Machines*, NavPers 10624. Read it carefully.

SUMMARY

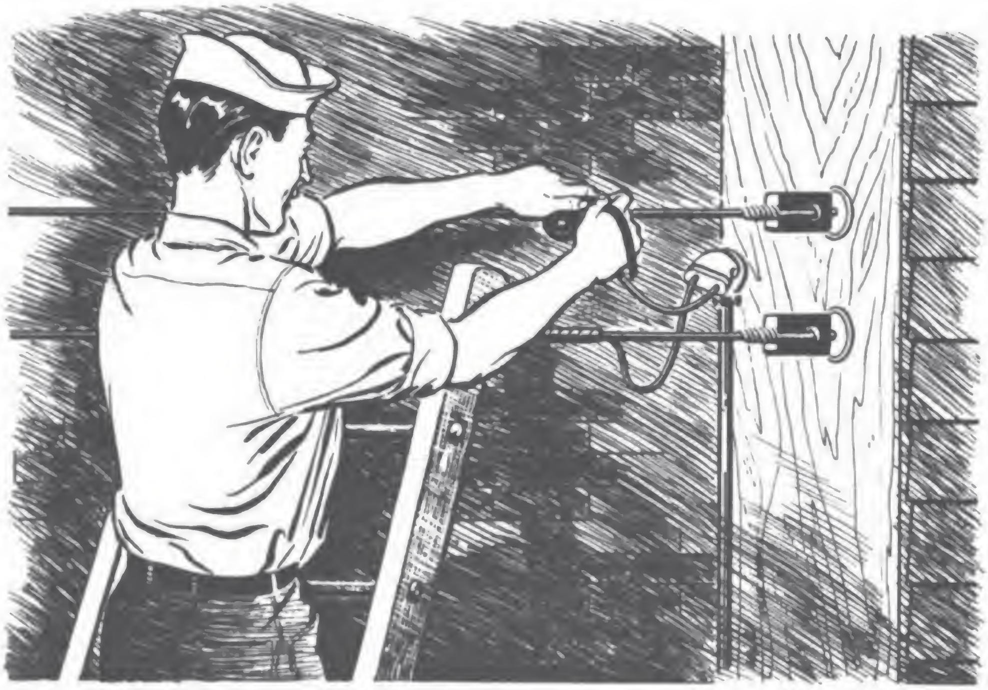
All the training manuals which have just been discussed are listed below. Don't forget that you may obtain them from your educational office.

TITLE	*NavPers No.*
General Training Course for Non-Rated Men	10601
General Training Course for Petty Officers	10602-A
Mathematics, Vols. 1 and 2	10069, 10070
Use of Blueprints	10621
Electricity	10622
Use of Tools	10623
Basic Machines	10624

Remember—READ carefully, ASK questions, and you "CAN DO."

QUIZ

1. What do the following stand for: (a) CE; (b) CEG; (c) CEP; (d) CEL?
2. What is the quals chart?
3. Where can the military requirements for your rate be found?
4. List seven textbooks (titles only) which you must read before you may successfully master the material in this book.
5. Where can you secure these books?
6. Why is it necessary for you to study *Basic Machines* in order to become an Electrician?
7. What is a series circuit?
8. What is a parallel circuit?



CHAPTER 2

WORKING WITH CONDUCTORS

A COMMON MATERIAL

As a Construction Electrician you have to be a good all-round man. A quick look at the qualifications chart in the appendix will convince you of that. But whether you repair motors, work on power lines, or install telephones, you will be using one common material—the conductor.

A CONDUCTOR is one wire, or a group of wires not insulated from each other. Its job is to provide an EASY path for electric current. That's why you'll find all conductors made of metal. Silver would be the best metal to use, because it puts up the least resistance to current flow. Copper runs a close second. Silver is expensive, but copper is cheap and easy to solder. Therefore, most of the conductors you work with will be made of copper.

WIRES AND CABLES

You'll find that conductors are classified as either wire or cable. A wire is a SINGLE, SOLID conductor. A cable may be a STRANDED conductor (single-conductor cable), or a GROUP of conductors insulated from each other (multiconductor cable). Figure 6 shows you some typical wires and cables.

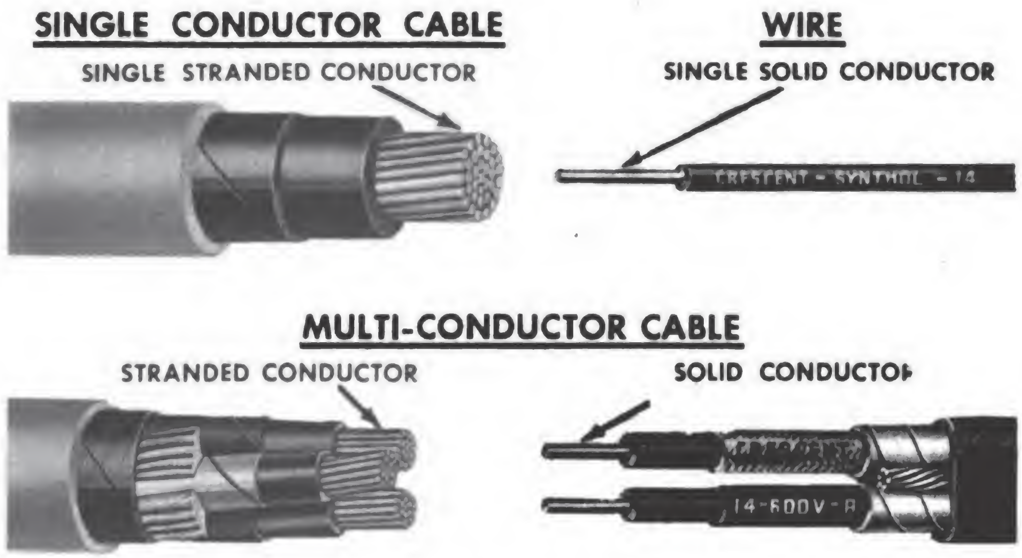


Figure 6.—Cables and wire.

You may be wondering why it is necessary to have both solid and stranded conductors. The answer is flexibility. Some of the work you do will call for large-sized cable to be "snaked" through some pretty sharp curves. You would find a large, solid conductor hard to handle in this type of job. Use a stranded conductor, made up of a number of small wires, and your problem is licked.

CONDUCTOR INSULATION

In some respects you can compare an electrical system to a water system. You know that in a water system the pipes carry the water from the storage tank to the user. You also know that in the electrical system, the wires carry the electrical

current from the generator, where it is produced, to the user. If a part of the water-pipe system should develop a leak, the water would be lost. If a bare wire of the electrical system should touch some other wire or similar conductor, the current would follow another path. Then you would have a short circuit on your hands.

The next time you get a chance, look at the wires strung on a telephone pole. You'll discover that in most cases they are uninsulated. Take another look, though, and you'll see they are kept apart by tying each wire to an insulator on the crossarm.

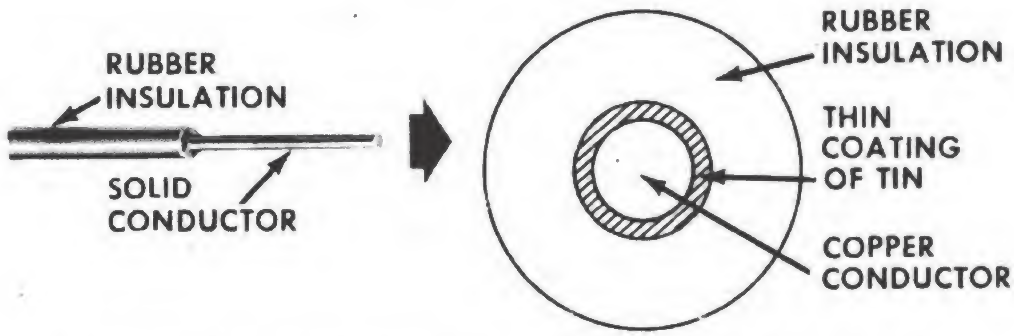
Not all of the wires you work with, however, will be strung on poles. Some are used for the interior wiring of buildings, others are placed underground or under water. To conserve space, these wires must be placed close to each other. That means each wire must be covered with a nonconducting or insulating material to prevent short circuits. The type of insulation which is used depends on the voltage the wire carries, and the operating conditions it must meet.

Rubber

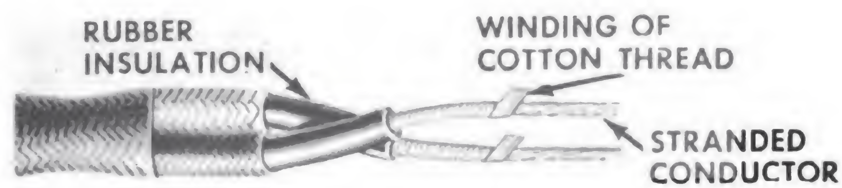
The most common insulation that you will find on wires is rubber. Rubber-covered (RC) wire is used quite a lot in buildings and underwater work. The voltage the wire carries will determine the thickness and grade of rubber used. The higher the voltage, the thicker must be the rubber. Figure 7 shows you two types of rubber-covered wire. One is a single, solid conductor, and the other a multiconductor cable in which each stranded wire is covered with rubber insulation. In each case the rubber serves the same purpose: to keep the current inside the conductor.

If you take a close look at the enlarged cross-sectional view in figure 7, you will notice that there is a material which separates the copper conductor from the rubber insulation. It's put there because rubber and copper just don't get along. As the result of a chemical action, rubber becomes soft and gummy when it comes in contact with copper. In the case of a solid conductor, you'll find a thin coating of tin between the copper and rubber.

When small, stranded conductors are used, you will discover a winding of soft cotton threads.



RUBBER INSULATED SOLID CONDUCTOR



RUBBER INSULATED STRANDED CONDUCTOR

Figure 7.—Rubber insulation.

Varnished Cambric

If you've read *Electricity*, NavPers 10622, you know that heat is developed when current flows through a wire. You have also learned that as the amount of current increases, the heat increases. You might be wondering what all this has to do with the insulation of conductors. The answer is QUITE A LOT! Some cables are used for power work which involves high current flow. This means that the insulation must withstand a large amount of heat. If the insulation were to break down, it would fail in its job.

Rubber is a good insulator as long as the temperature doesn't

climb too high. Too much heat will cause even the best grade of rubber insulation to become brittle and crack. That's where VARNISHED CAMBRIC steps into the picture. Varnished cambric is nothing more than cotton cloth that has been coated with an insulating varnish. Figure 8 gives you an idea of the appearance of a varnished cambric (VC) cable. Notice that the varnished cambric is in tape form and wound around the conductor in layers.

Figure 8.—Varnished cambric insulation.

What you can't see in the picture is an oily compound which is applied between each layer of the tape. This compound prevents water from seeping through the insulation. It also acts as a lubricant between the layers of tape, so they will readily slide on each other when the cable is bent.

You will use varnished cambric cables in switchboards of powerhouses because of its ability to resist high operating temperatures. You will also use it on generator and transformer leads, because it is not affected by oils or grease.

Asbestos

You've just read about varnished cambric. You know that it's used as an insulating material instead of rubber because it is able to withstand more heat. If you get right down to brass tacks, however, you'll find that even varnished cambric will break down when the temperature climbs above 85° C. You might find it necessary to install wiring in some hot places; that is, where the temperature exceeds 85° C. You might also find yourself wiring an electrical device which draws a considerable amount of current—that also means high temperature

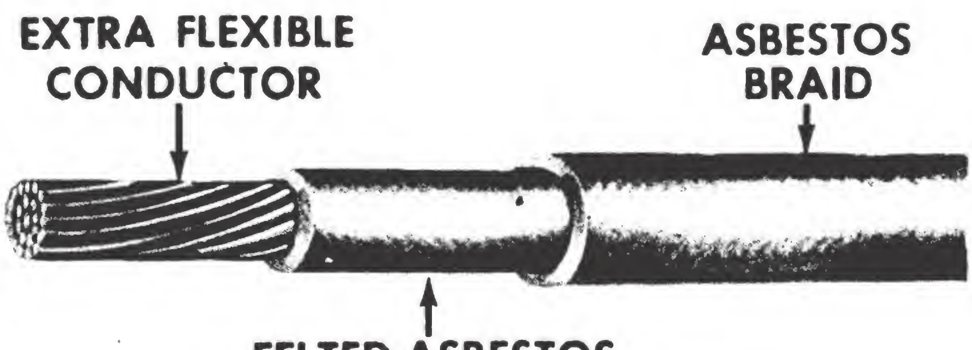


Figure 9.—Asbestos insulation.

For a job of this kind you can't use rubber or varnished cambric for insulation, but you can use ASBESTOS.

Asbestos is the perfect insulation for wires and cables used in very high temperature work. It is absolutely fire-resistant and never changes with age. One type of asbestos-covered (AC) wire is shown in figure 9. It consists of just the stranded copper conductor covered with felted asbestos. When you wire motion-picture projectors, arc lamps, and spotlights, you will use this type of wire.

Another type of asbestos-covered cable is pictured in figure 10. It serves as leads for motors and transformers which must operate in hot, wet locations. If you take a close look, you will find a layer of varnished cambric covering the asbestos. The varnished cambric is put there for a purpose. Asbestos has the

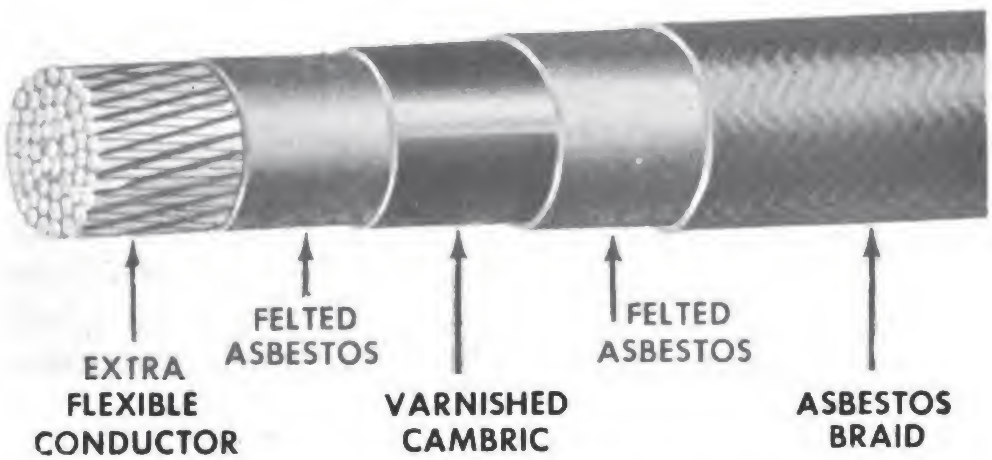


Figure 10.—Asbestos and varnished cambric.

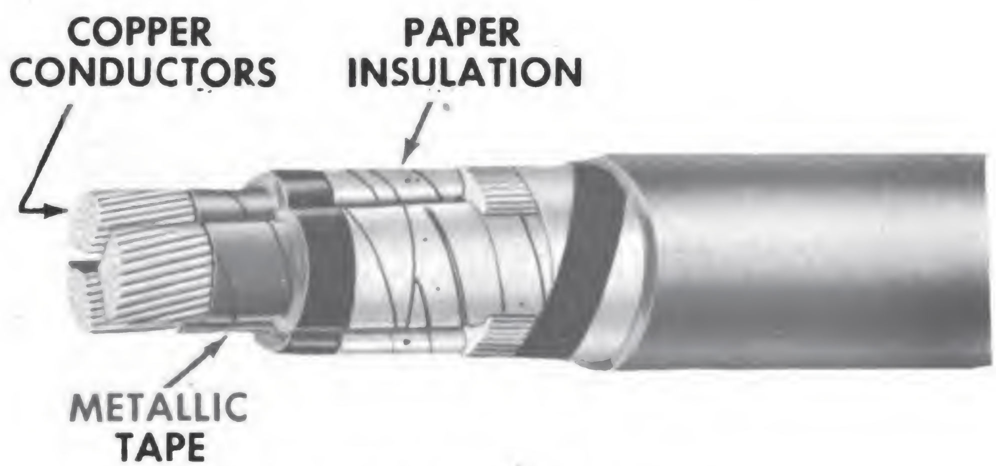


Figure 11.—Paper-insulated cable.

bad habit of breaking down when it becomes wet. In fact, it then changes from an insulator to a conductor. The varnished cambric will prevent this from happening, since it resists moisture.

Paper

You know that 75,000 volts is a lot of electrical pressure. Ordinary cable and wire just couldn't handle it. Rubber, varnished cambric, or asbestos insulation would break down under that tremendous strain. That's where PAPER comes through with flying colors.

Wherever cables are required to carry very high voltages, you will find them insulated with paper. The paper, which is very thin, is applied to the conductor in the form of tape. It is then soaked in a heavy oily mixture.

The multiconductor cable shown in figure 11 is a paper-insulated cable. It may be used to carry high voltages overhead, underground, or under water. Notice the metallic tape between the copper conductor and the oil-soaked paper insulation. It is put there to reduce the reaction between the copper and the oil.

Silk and Cotton

Some of your work may involve telephone communications. If it does, you will be working with a large number of individual circuits. Some telephone switchboards may have as high as 303 separate talking circuits. That means you have to use a cable containing 303 pairs of wires.

Seeing is believing. Take a look at figure 12. It shows you a

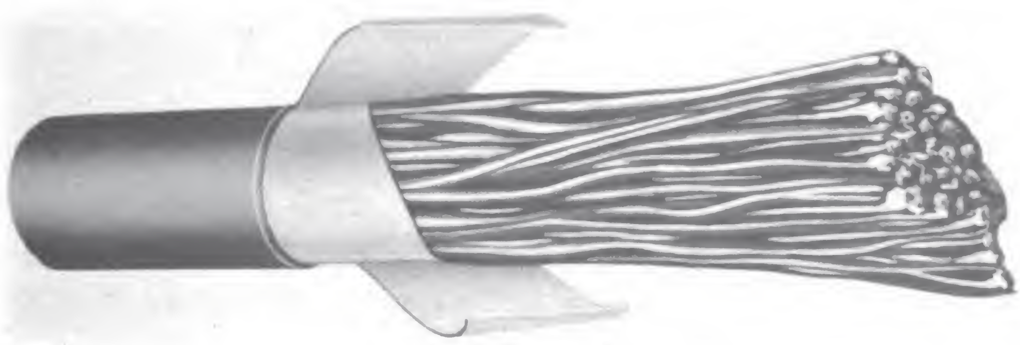


Figure 12.—Silk and cotton insulation.

switchboard cable containing 303 pairs of wires. Each wire is separated by an insulation of SILK and COTTON threads. Using silk and cotton as insulation keeps the size of the cable small

enough for it to be easily handled. The silk and cotton are wrapped around each conductor in reversed directions and then soaked with a special wax compound.

Enamel

You should be familiar with an electromagnetic coil. It is simply a number of continuous turns of wire wound around a metal core or air space. When current flows through the wire, a magnetic field is set up. The coil becomes a magnet with a north and south pole.

Coils used in electrical meters and relays are the ones you will work with the most. You will find that these coils contain a large number of turns of small wire, called magnet wire. To

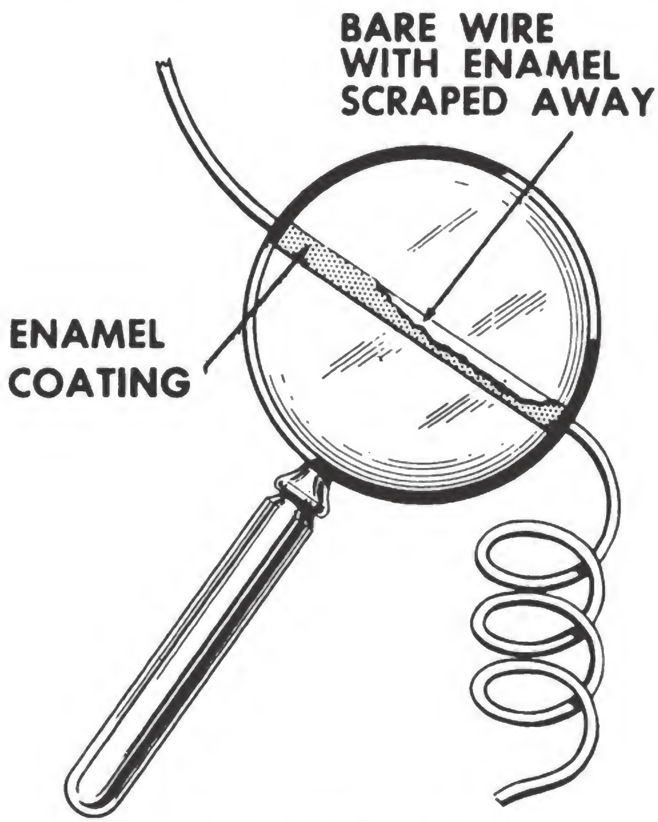


Figure 13.—Enamel insulation.

keep the size of the coil down to a minimum, the wire is covered with a thin coating of ENAMEL. Since the wires carry a small current, the enamel coating is all the insulation that is needed.

Figure 13 gives you a picture of enamel-coated wire. The wires of the coil have been purposely spread apart so you can be shown an enlarged view of the enamel insulation.

Here's a word of caution! If you ever find it necessary to rewind a coil with enamel-insulated wire, handle the wire with care. Otherwise you might nick or scratch the enamel coating, which could cause a short circuit.

CONDUCTOR PROTECTION

Wires and cables must be able to take it. No matter where you install them, they are subject to some abuse. Cables buried directly in the ground must resist moisture, chemical action, and abrasion. Wires installed in buildings must be protected against mechanical injury. You can't even consider the wires strung on poles as being "safe." It's true that they are kept far enough apart so they can't touch each other, but how about the effects of Old Man Weather? Snow, ice, and strong winds can deal out a lot of punishment.

The protection for a wire or cable is in the form of an outer covering. The material used for the outer covering depends, of course, on the conditions the wire or cable must meet. Generally speaking, though, you'll find protective coverings divided into two main classes: metals and nonmetals. They are discussed below in more detail.

Fibrous Braid

Cotton, linen, silk, rayon, and jute are types of FIBROUS BRAIDS. They are used for outer coverings wherever the wires or cables are NOT exposed to heavy mechanical injury. Any interior wiring that you do will probably be with braid-covered conductors, insulated with rubber. In most cases the wires will be further protected by a conduit or steel pipe.

Figure 14 shows you a typical building wire. In this instance there are two braid coverings, for extra protection. The outer braid is soaked with a compound which resists moisture and flame.

You'll find cotton braid used as a covering for uninsulated wire, too. This is called a weatherproof covering. You will discover this type of protection on overhead wires which do not have to be insulated, but must be protected against contact with tree branches and other objects.

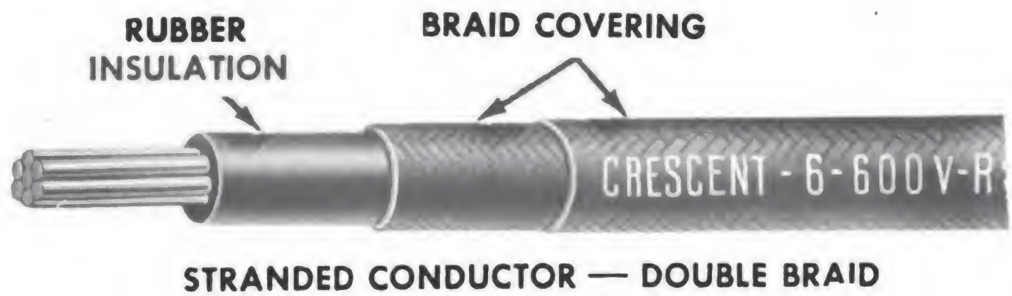


Figure 14.—Fibrous braid covering.

Lead Sheath

Cables or wires which are continually under attack by moisture and oils must be protected by a watertight cover. This watertight cover is made of a continuous LEAD JACKET or sheath molded around the cable.

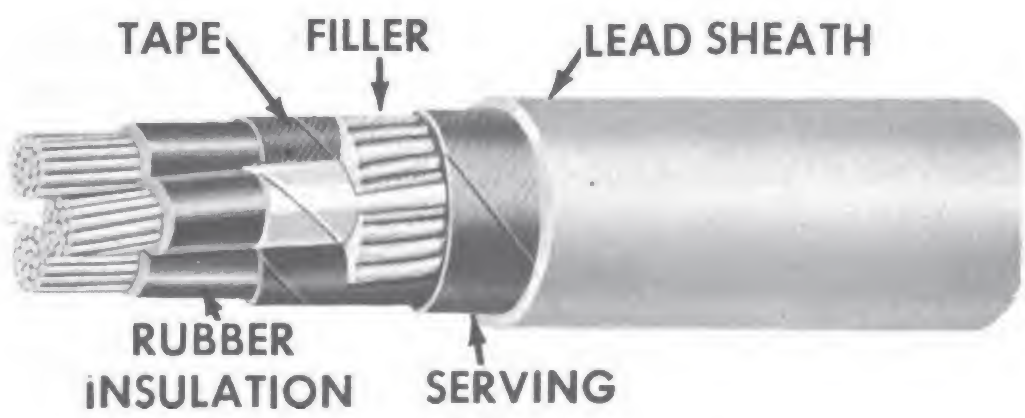


Figure 15.—Lead-sheathed cable.

Figure 15 is a good example of a lead-sheathed cable used in power work. The cable shown is a stranded three-conductor type. If you'll take a look at its construction, you will see that each conductor is insulated with rubber and then wrapped with a layer of rubberized tape. The conductors are twisted to-

gether and FILLERS of rope are added to form a rounded core. Over all of this is wrapped a second layer of rubberized tape, and finally the lead sheath. The rubber tape is called a SERVING. It's put there for mechanical protection. It prevents the lead sheath from rubbing against the insulation and injuring it. Serving may be made of material other than rubberized tape, of course.

The cable shown in figure 15 is only one type of lead-covered cable you will work with. Telephone cable is also lead-sheathed. If you can't remember what it looks like, turn back to figure 12. No filler is needed here, but a serving is used. In this case it is simply a double wrapping of paraffin-soaked paper.

METALLIC ARMOR

Have you ever seen a picture of a knight in armor? You know that he wasn't wearing it for its good looks, but because it offered protection from the heavy blows of his enemy.

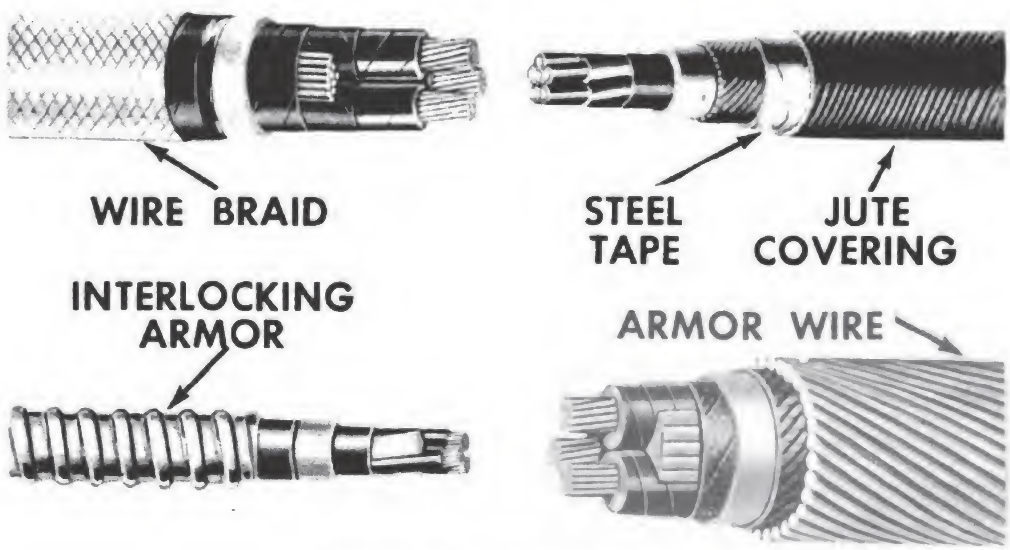


Figure 16.—Metallic armor.

A wire or cable, too, may be exposed to heavy blows. If it is to do its job, it must also be protected by a suit of armor. In this case the thickness of armor and the type of metal used depend on the strain which the wire or cable must meet. Four types of metallic armor for cables are shown in figure 16.

You will find the WIRE BRAID armor used wherever light, flexible protection is needed. The individual wires which are woven together to form the metal braid may be made of steel, copper, bronze, or aluminum. Besides mechanical protection, the wire braid also presents a static shield. This is important in radio work to prevent interference from stray magnetic fields.

When cables are buried directly in the ground, they might be injured from two sources: moisture and abrasion. They are protected from moisture by a lead sheath, and from abrasion by STEEL TAPE OR INTERLOCKING ARMOR covers. The steel tape covering, as shown in figure 16, is wrapped around the cable and then covered with a serving of jute. It is known as Parkway cable. The INTERLOCKING ARMOR covering can withstand impacts better than steel tape. Interlocking armor has other uses besides underground work. When you are wiring the interior of a building that has no conduit, you will probably use interlocking armor-covered wire.

ARMOR WIRE is the best type of covering to withstand severe wear and tear. If you ever have to lay underwater cable, it will probably have an armor wire cover.

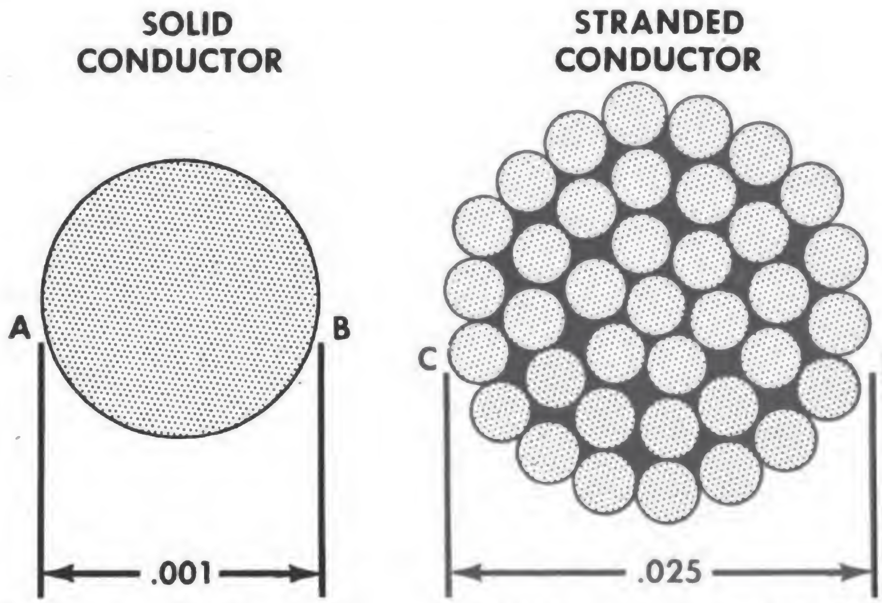
Here's something you should remember. Not all the wire and cable you work with will have just one type of protective covering. Some coverings are designed to withstand moisture, others mechanical strain. That means you may run across a cable that has a combination of each type, each doing its own job.

MEASURING THE CONDUCTOR

You've been introduced to the conductor, the insulation, and the protective covering. You know what they are, and the job that each has to do. You're all set to start working on wires and cables. Or are you? How about the sizes of conductors? If you don't know how to measure a conductor, you have one more thing to learn.

The size of a conductor is measured by the thickness of its cross section. If you're in doubt as to the meaning of cross section, take a look at figure 17. It shows you the cross section of a solid and stranded conductor. It's nothing more than a

head-on view. The thickness of the solid conductor is the distance between points *A* and *B*, measured along the diameter of the circular cross section. When you measure stranded wire, you must determine the length of its over-all diameter. In figure 17 it is the distance between *C* and *D*.



DIAMETER = .001 INCHES
DIAMETER = 1 MIL
CIRCULAR MIL AREA = $(D)^2$
C.M.A. = 1 x 1 = 1

DIAMETER = .025 INCHES
DIAMETER = 25 MILS
CIRCULAR MIL AREA = $(D)^2$
C.M.A. = 25 x 25 = 625

Figure 17.—Measuring solid and stranded conductors.

Most of the conductors you work with will have small diameters. They are measured in thousandths of an inch. In decimal form a thousandth of an inch is 0.001 inches. To make it easier for you, the term MIL has been substituted for 0.001 inches. In other words, 1 mil equals one thousandth of an inch. For example, the solid conductor in figure 17 has a diameter of 0.001 inches, or 1 mil. The stranded conductor has a diameter of 0.025 inches or 25 mils. You can see that when you use mils, you work with whole numbers instead of fractions or decimals.

Sometimes it is convenient to express the size of a conductor by the area of its cross section. Figuring out cross-sectional

A.W.G.	Diameter in mils (d)	Area in circular-mils (d^2)	Ohms per 1,000 feet at 20° C. or 68° F.
1	2	3	4
0000	460. 00	211, 600	0. 04893
000	409. 64	167, 810	. 06170
00	364. 80	133, 080	. 07780
0	324. 86	105, 530	. 09811
1	289. 30	83, 694	. 1237
2	257. 63	66, 373	. 1560
3	229. 42	52, 634	. 1967
4	204. 31	41, 742	. 2480
5	181. 94	33, 102	. 3128
6	162. 02	26, 250	. 3944
7	144. 28	20, 816	. 4973
8	129. 49	16, 509	. 6271
9	114. 43	13, 094	. 7908
10	101. 89	10, 381	. 9972
11	90. 742	8, 234. 0	1. 257
12	80. 808	6, 529. 9	1. 586
13	71. 961	5, 178. 4	1. 999
14	64. 084	4, 106. 8	2. 521
15	57. 068	3, 256. 7	3. 179
16	50. 820	2, 582. 9	4. 009
17	45. 257	2, 048. 2	5. 055
18	40. 303	1, 624. 3	6. 374
19	35. 890	1, 288. 1	8. 038
20	31. 961	1, 021. 5	10. 14
21	28. 462	810. 10	12. 78
22	25. 347	642. 40	16. 12
23	22. 571	590. 45	20. 32
24	20. 100	404. 01	25. 63
25	17. 900	320. 40	32. 31
26	15. 940	254. 10	40. 75
27	14. 195	201. 50	51. 38
28	12. 641	159. 79	64. 79
29	11. 257	126. 72	81. 70
30	10. 025	100. 50	103. 0
31	8. 928	79. 70	129. 9
32	7. 950	63. 21	163. 8
33	7. 080	50. 13	206. 6
34	6. 305	39. 75	260. 5
35	5. 615	31. 52	328. 4
36	5. 000	25. 00	414. 2
37	4. 453	19. 82	522. 2
38	3. 965	15. 72	658. 5
39	3. 531	12. 47	830. 4
40	3. 145	9. 89	1, 047

Figure 18.—American wire gage table.

areas becomes easy when you use mils as the unit of measurement. That's because a circle which has a diameter of one mil has an area of one CIRCULAR MIL. Therefore, you can determine the circular mil area of any round conductor by SQUARING ITS DIAMETER IN MILS. As an example, the area of the solid conductor in figure 17 is found by multiplying its diameter (1 mil) by itself: 1 mil x 1 mil = 1 circular mil. The area of the stranded conductor is 25 mils x 25 mils or 625 circular mils.

Wires are made by a number of different manufacturers, and yet they all conform to one standard of measure. It is called the AMERICAN WIRE GAGE (AWG). When you use the American wire gage, you indicate the size of a wire by a number instead of mils or circular mils. A No. 10 wire, for example, has a cross-sectional area of 10,384 circular mils. The chart in figure 18 gives you the complete picture. If you'll check it, you will find that the gage numbers range from 40 to 0000.

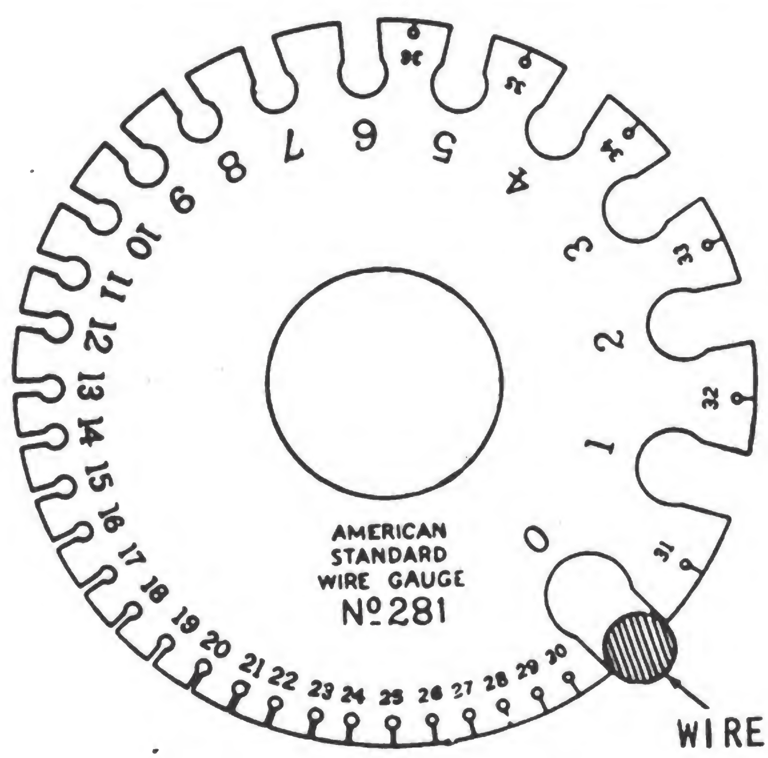


Figure 19.—Using the wire gage.

After No. 0000, also termed 4/0, wire is reached, the circular mil area is again used to denote wire size. Chalk this down as

something to remember—the gage numbers are in reverse order; that is, the larger the number, the smaller the size of wire.

Some wires and cables have the conductor size stamped on the outside covering—others don't. If you aren't sure as to the size of any wire, it can easily be determined with a tool known as a wire gage. The wire gage is shown in figure 19. It is a round disk with different size notches punched along its edge. Each notch represents a wire size and has the American wire gage number marked alongside it. When you want to measure a wire or cable, you simply strip the insulation and find the notch into which the BARE conductor fits. The wire being measured in figure 19 fits into the 1/0 gage slot. Notice that it is the opening at the edge which determines the wire size, and not the hole farther back of the notch.

CONDUCTOR SPLICES

The way you splice or join conductors together is the best indication of your worth as an electrician. A poor job means a careless man--one who has no interest in his work. The splicing of conductors is important since AN ELECTRICAL SYSTEM IS ONLY AS GOOD AS ITS WORST SPLICE. If a splice fails, because of poor workmanship, the electrical system fails.

A good splice must have the same strength and electrical conductivity as the wires it joins together. You know you have a strong splice when it can stand the same pull as any other part of the wire. You know you have good electrical conductivity when there is no increase in resistance at the splice.

Preparing the wires for splicing is the first step you must master. Have you ever sharpened a pencil with a knife? You removed the wood by cutting it off almost parallel with the lead. This prevented you from breaking the lead shaft. When you "skin" the insulation from a wire, you follow the same plan. The knife is passed through the insulation almost parallel to the conductor. This produces a "penciled" effect, as shown in figure 20. Don't cut the insulation off at right angles to the conductor. The sharp edge of the knife will nick the conductor

and weaken it. If the wire has an outer covering, you should cut it back a short distance from the end of the insulation.

Use the back edge of your knife to scrape all traces of dirt and insulation from the bare conductors. Doing this insures good electrical contact and easy soldering. If you are working with solid rubber-insulated wire, don't disturb the coating of tin, which helps make soldering easier. When you are splicing stranded wire, take time to clean each individual wire. This pays off when you solder the wires together.

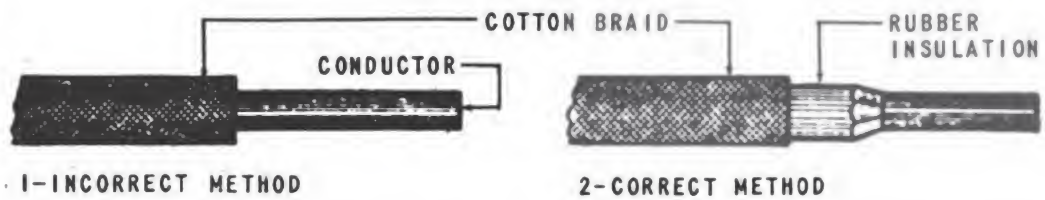


Figure 20.—Right and wrong methods of "skinning" wire.

Western Union

Small solid conductors may be joined together and extended with a very simple splice known as the WESTERN UNION. In most instances you can twist the wires together with your fingers and finish the ends off with pliers.

Figure 21 shows you the five steps in making a Western Union splice. In step 1, you prepare your wires for splicing by removing about 3 inches of insulation. Be sure to clean the conductor. Next (step 2) you bring the wires into a crossed position, about 1 inch from the insulation. Then you form a cross, as in step 3, by making a long twist or bend in each wire. Now you take one of the wire ends and make a tight wrapping of four or five short turns. This is shown in step 4. You complete your splice in step 5 by wrapping the remaining end in the same manner.

Here's a precaution you should observe! Cut off the ends of each wrapped wire and press them down as close as possible to the straight portion of the wire. If you do this, you will prevent the sharp ends from cutting through the tape covering which you wrap over the splice.

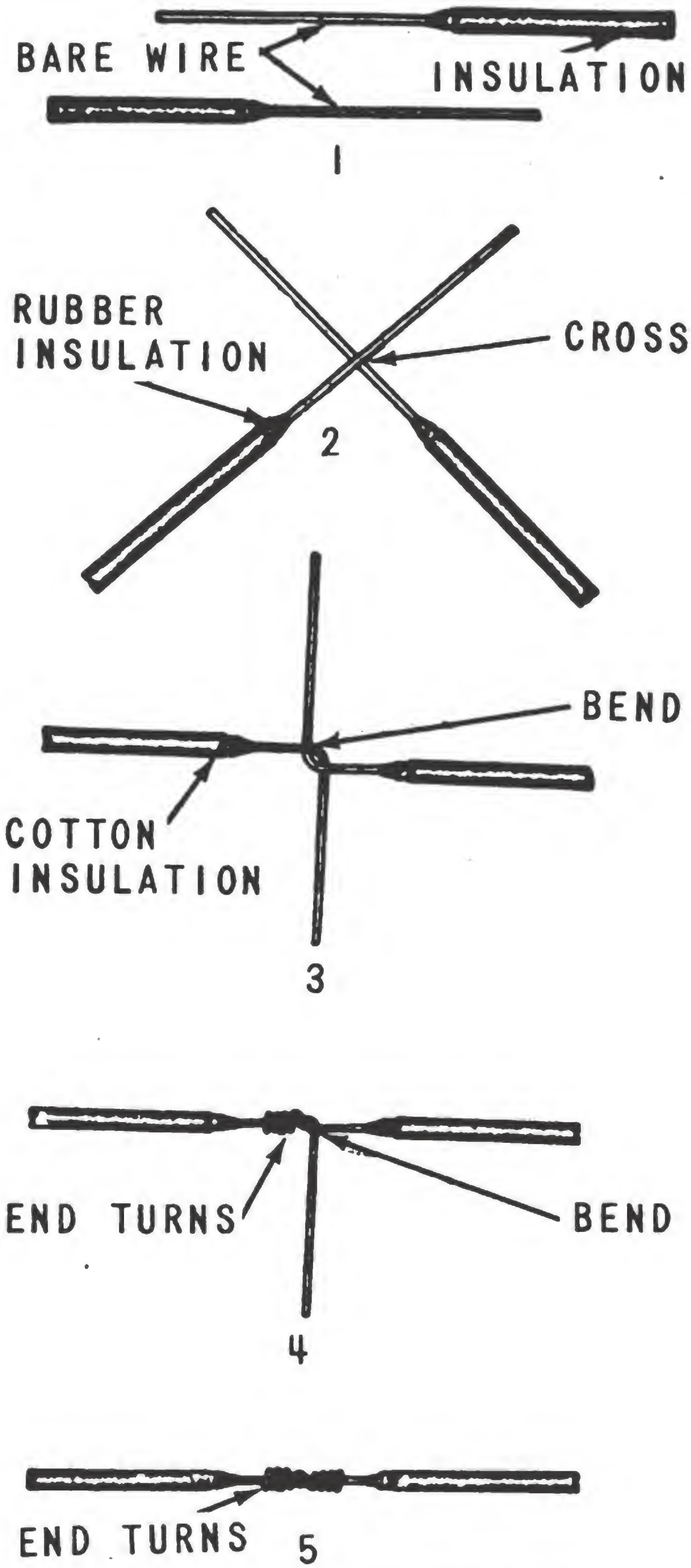


Figure 21.—Making a Western Union splice.

Duplex

When you join small, multiconductor cables together, you have a problem on your hands. Each conductor must be spliced and taped. If the splices are directly opposite each other, the over-all size of the joint becomes large and bulky. You can solve this problem by staggering the splices.

Figure 22 shows you how a two-conductor cable is joined to a similar cable using the DUPLEX SPLICE. Step 1 consists of the initial preparation of the conductors. This is the point where you stagger the splices. About 8 inches of the braid covering

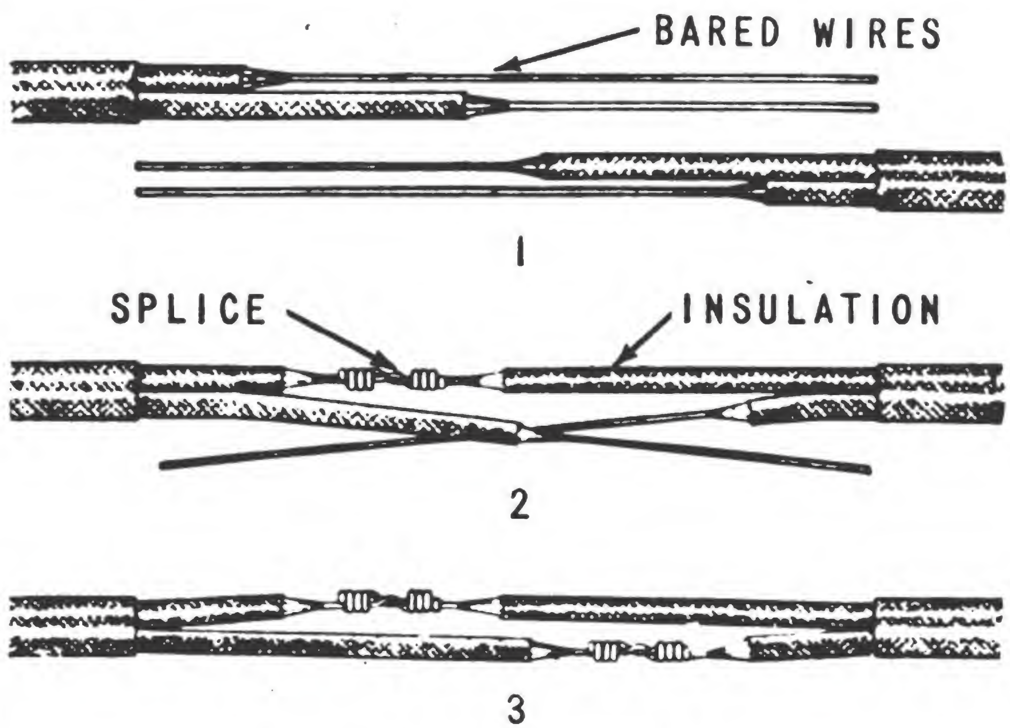


Figure 22.—Making a staggered splice.

is removed from each cable. You do this by cutting through the braid only and slipping it off over the ends of the cable. You then skin the rubber insulation from the wires so as to give you UNEQUAL lengths of bare conductors. The finished stagger looks like that shown in step 1. The short wire of each cable is bared for a distance of 3 inches, the long wire about 5 inches.

Now you are all set to splice the wires together as shown in steps 2 and 3. A common Western Union splice is used. Just

be sure that you join short wire to long wire, and that you take care of any sharp ends.

Rat-tail Joint

Wiring that is installed in buildings is usually placed inside of long lengths of steel pipe or conduit. Whenever the wires must be spliced, they are brought out of the conduit into splicing chambers or outlet boxes. The type of splice which you will use is termed a RAT-TAIL JOINT. Steps 1, 2, and 3 of figure 23 give you the full picture in making a rat-tail joint.

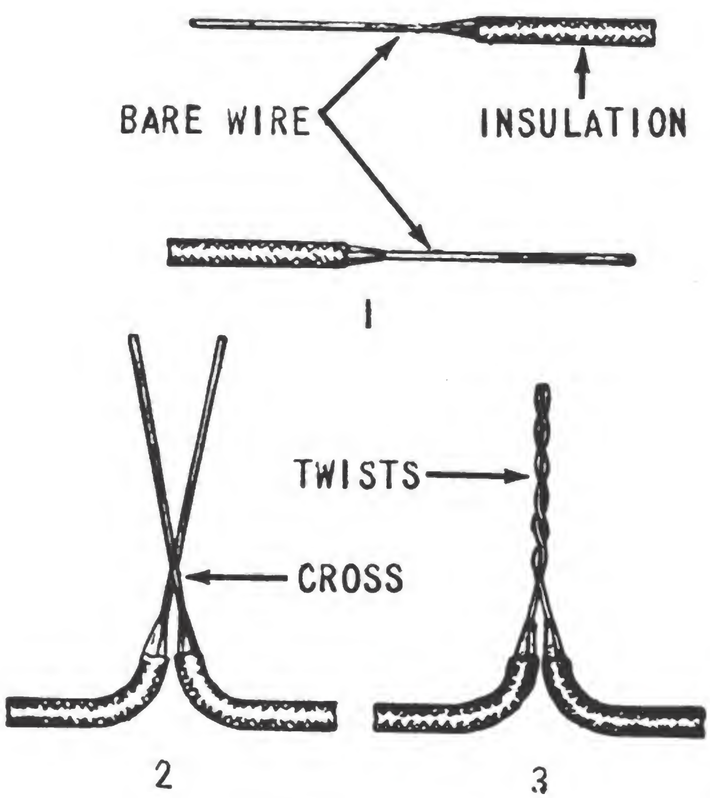


Figure 23.—Making a rat-tail joint.

The ends of the conductors to be joined are stripped of about 2 inches of insulation (step 1). You then begin the splice by crossing the conductors about one-quarter of an inch away from the insulation (step 2). This is followed through by twisting the two wires together to form a rat- or pig-tail effect (step 3).

Fixture Joint

As the name suggests, a FIXTURE JOINT is a splice you will use when connecting a light fixture to the branch line of an electrical system. Like the rat-tail joint, it is a splice that won't stand too great a mechanical strain.

Your first step in making the splice consists of removing the insulation from the fixture wires and from the branch wires. About 3 inches of insulation is stripped from the fixture wires and 1 inch from the branch wires. When you have finished, the wires will look like those in step 1 of figure 24. Only one wire of the fixture and one of the branch is shown being spliced. The other wires are joined in exactly the same way.

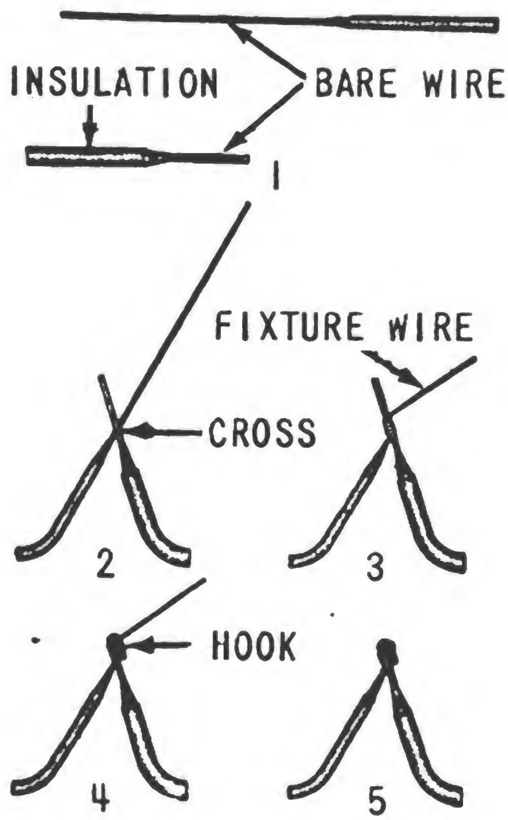


Figure 24.—Making a fixture joint.

After completing step 1, you cross the conductors over in a manner similar to the rat-tail joint (step 2). Now you take the long wire and wrap it tightly around the short conductor. Make about four or five turns and stop. Your work will then appear

as in step 3. Notice that the wires are NOT TWISTED TOGETHER as in the rat-tail joint. Your next step (4) consists of making a hook with the remaining end of the branch wire by bending it over the completed turns. You put the finishing touches to the splice (step 5) by wrapping the end of the fixture wire over the hook. Soldering and taping complete the job.

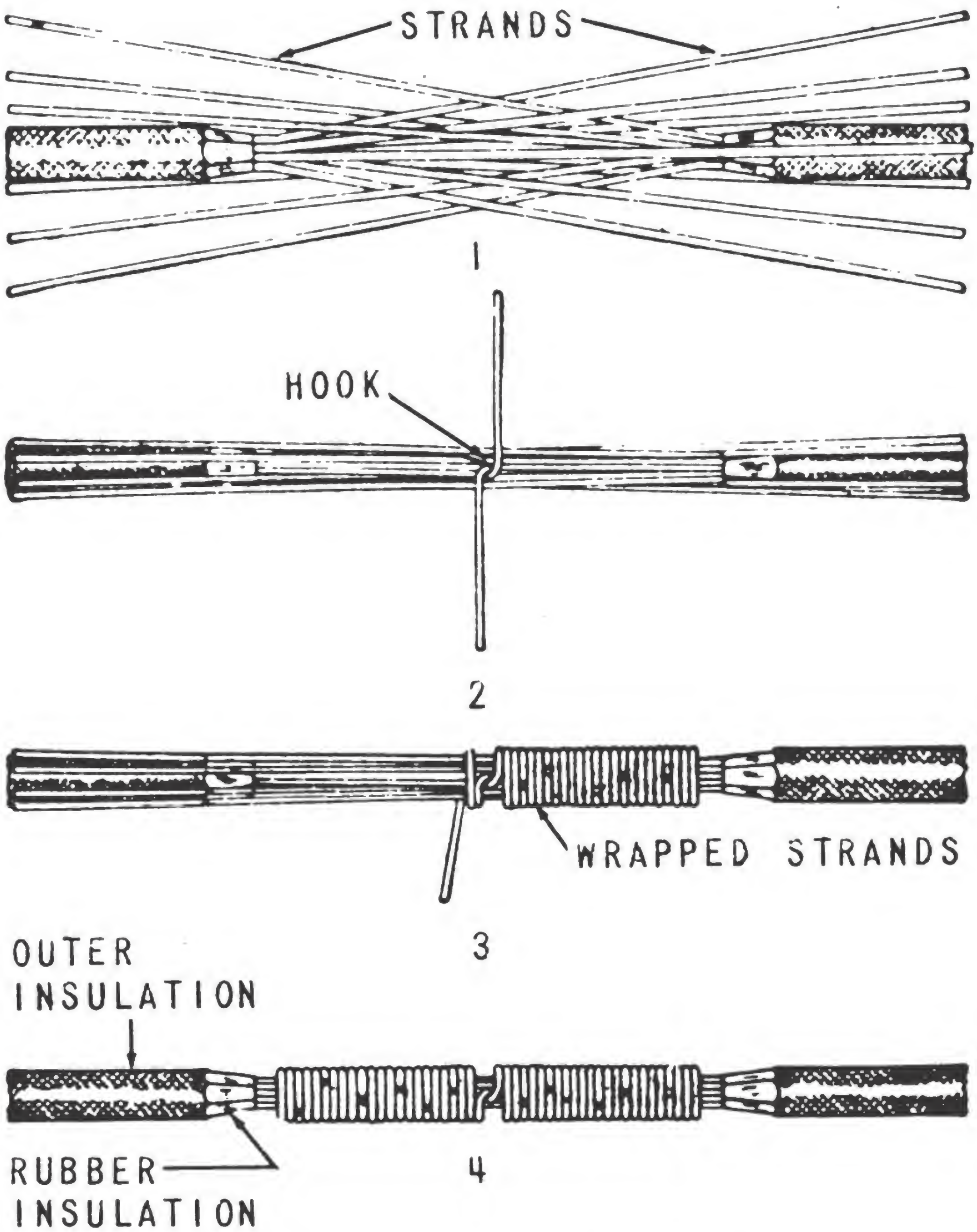


Figure 25.—Making an ordinary wrapped splice.

Wrapped

Small, stranded cable can be joined together with the common Western Union splice. The larger sizes require a different type of splice. It is called a WRAPPED SPLICE because that is exactly what you do with each wire of the stranded conductors. The wrapped splice is one type of splice you will have to do a lot of practicing on.

Figure 25 shows you the four steps in making an ordinary wrapped cable splice. Before you get to step 1, of course, you've got to prepare the ends of the cables. That means stripping the outer coverings and insulation in the correct manner and cleaning EACH strand of wire.

You get the result shown in step 1 by spreading each strand slightly apart and then bringing the two cables together in a laced effect. In step 2 you take any two oppositely faced strands and cross them over each other. Both of these strands are now at right angles to the cable run. In step 3 you wrap one of the two strands tightly around the main part of the cable. Where this strand ends, you pick another going in the same direction and wrap it around the cable. You continue this process until all the strands are used up on one side of the splice. It will look like step 3 after you get through. By doing the same thing to the strands going in the other direction, your completed splice will appear as in step 4.

Knotted Tap

All of the splices which you have studied up to this point are known as BUTTED splices. Each was made by joining the FREE ends of the conductors together. Sometimes, however, you will be called upon to join a conductor to a CONTINUOUS WIRE. This type of splice is known as a TAP.

The main wire, to which the branch wire is to be tapped, has about one inch of insulation removed. The branch wire is stripped of three inches of insulation. This is shown in step 1 of figure 26.

You start the splice by crossing the branch wire over the main wire as pictured in step 2. About three-quarters of the branch

wire extends above the crossing point. You then hook the branch wire over the main wire (step 3), and bring it down, under, and then over itself to form a knot (step 4). It is then wrapped around the main conductor in short, tight turns and the end trimmed off (step 5).

You'll discover the knot tap used where the splice is subject to strain and slip. When there is no mechanical strain on the splice, you can eliminate the knot. Just wrap the tap wire around the main wire as in step 5.

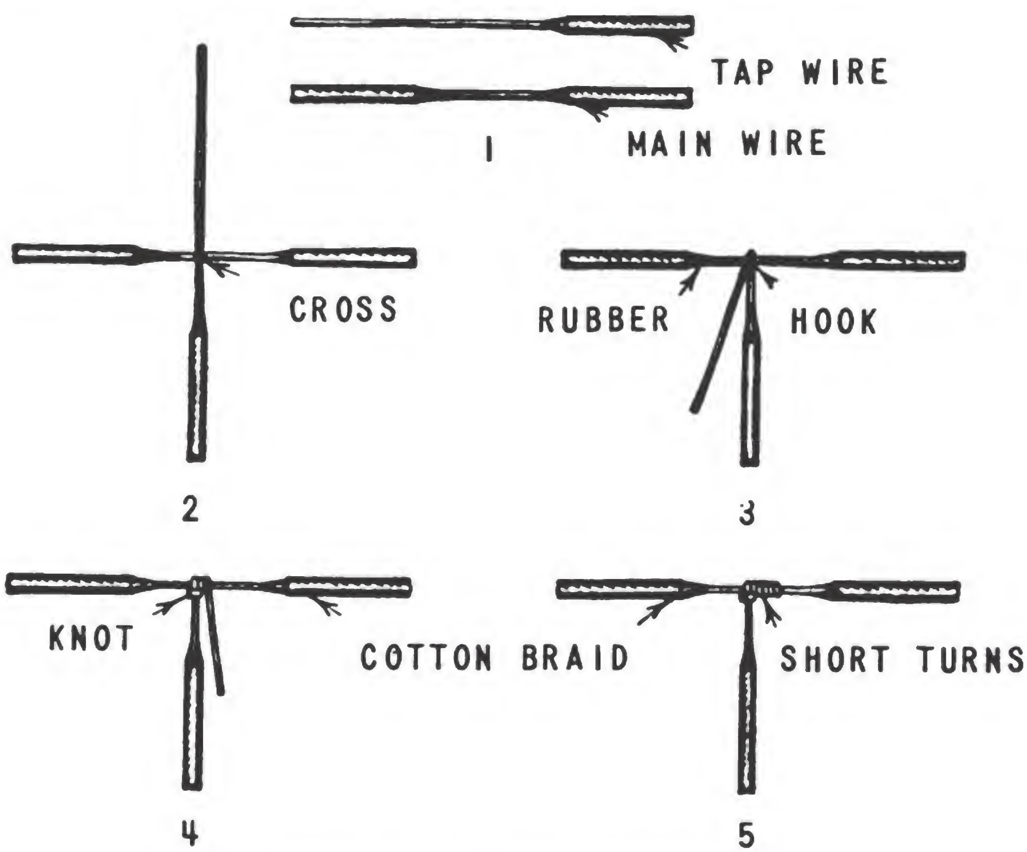


Figure 26.—Making a knotted tap.

SOLDERING THE SPLICE

Your splice is never completely finished until you have soldered and taped it. You were introduced to soldering when you read *Use of Tools*, NavPers 10623. If you are not entirely familiar with the following basic facts and terms, check back to NavPers 10623.

1. Soldering a splice helps to protect it from corrosion.

2. Solder is a low-melting-point alloy made up of tin and lead, and comes in both bar and wire form.

3. Rosin is the flux used in soldering electrical connections. You may apply it directly to the splice or in the form of rosin-core solder.

4. You can use either a soldering copper or a direct flame to sweat the solder to the splice. Small-sized wire can be soldered with a soldering copper. Large-sized wire requires a blowtorch or an alcohol torch.

5. "Tinning" a soldering copper is a must before you begin a soldering job.

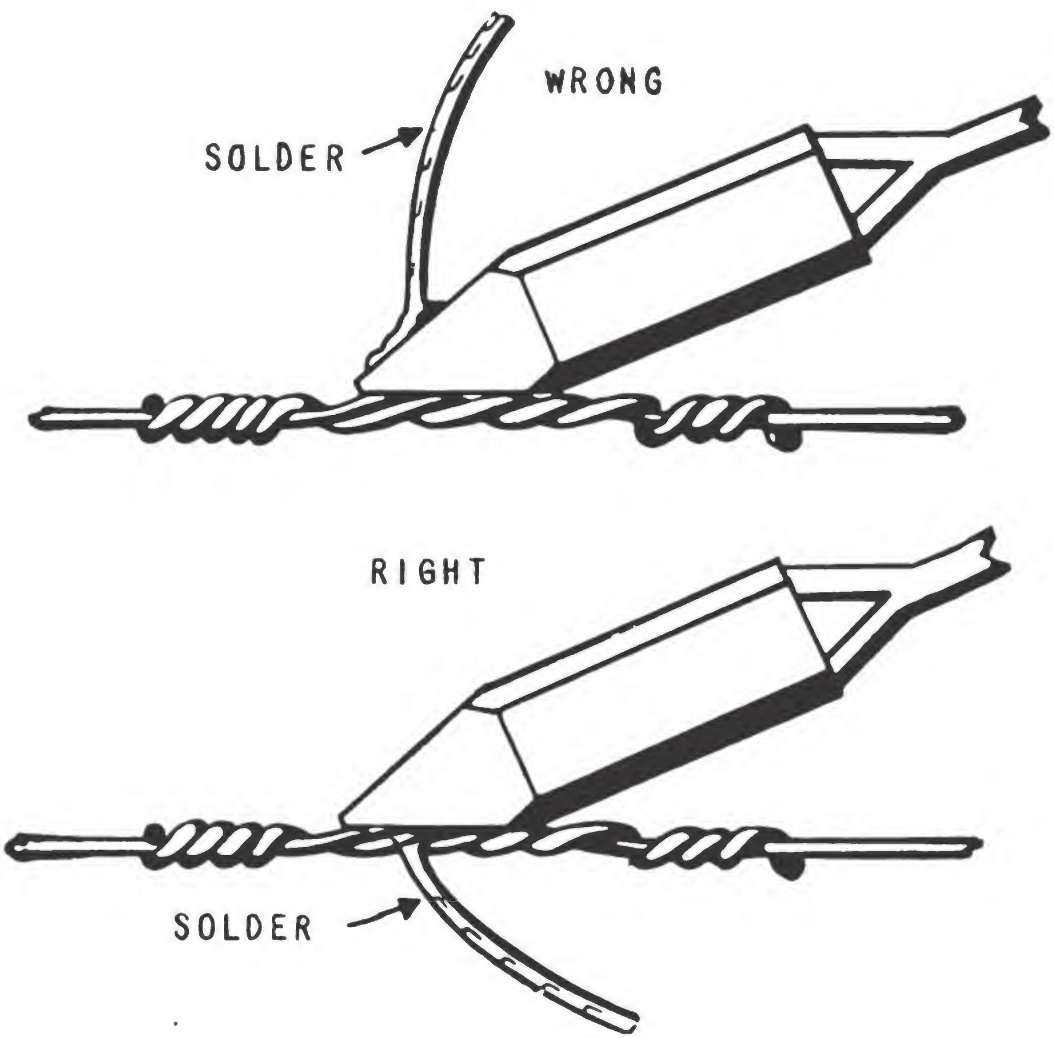


Figure 27.—Right and wrong methods of soldering.

The proper way to apply the soldering copper and the solder to the splice bears repeating. You will never get the solder to stick if the splice itself is not hot enough to melt the solder. When you apply the soldering copper to the splice, allow enough time for the splice to heat up. How do you know when the wire has reached the right temperature? Simple as ABC. Just apply the solder to the side of the splice opposite the soldering copper. When the solder melts, it's because the wire itself is hot enough to do it. The solder will flow into every crack and hidden space of the splice. Then you've got one more good soldering job to crow about! Figure 27 shows you the right and wrong methods of soldering.

TAPING THE SPLICE

A splice is like a wound or cut. If you don't cover it up, it can cause you a lot of trouble. Wrapping a splice is the final step in joining wires and cables.

Rubber Tape

When you join rubber-insulated, braid-covered wire together, you must first restore the insulation to the splice. To do this you use a rubber SPLICING COMPOUND. The word "compound" might lead you to believe the rubber is applied as a liquid. Actually, however, it is in the form of a RUBBER TAPE. You apply the tape to the splice with a slight tension so that each layer presses tightly against the one underneath it. This pressure causes the rubber tape to blend into one solid mass. When you end up, you have a continuous wall of rubber, just like the original insulation. If you don't believe it, wind a few layers of rubber tape around a pencil and then slice through it. You'll find that all the cracks have been completely sealed.

When you use the tape, you will discover a layer of paper between each layer of rubber. The paper prevents the layers of rubber from fusing while they are on the roll. Of course, you throw the paper away when you apply the rubber tape to the splice.

Figure 28 shows you the correct way to cover a splice with rubber insulation. You start winding the tape on at one end of the splice, beginning at the point where the original insulation ends. You must be sure to apply the overlapping turns of tape at a slight angle to the conductor and to use a tension or pull.

Figure 28.—Applying the rubber tape.

You can tell when you have the correct tension by checking the tape width. This should be stretched to about three-quarters of its original width. You continue wrapping the rubber tape until you reach the other end of the splice. At this point you reverse your direction and wrap a second layer of tape back to your starting point. It may be necessary for you to add a third layer. The thickness of your applied insulation should be slightly greater than that of the original insulation.

Friction Tape

Putting rubber tape over the splice means that you have restored its insulation. But how about the protective covering? When you spliced the wire you had to remove its covering, too. Replacing the covering is as important as replacing the rubber insulation. You can do this job easily with FRICTION TAPE.

Friction tape is a cotton cloth that has been soaked with a sticky rubber compound. The rubber is rubbed or "frictioned" into the cotton. Thus the name "friction tape." It comes in rolls just like rubber tape and is applied in the same manner. Unlike rubber tape, however, it doesn't stretch.

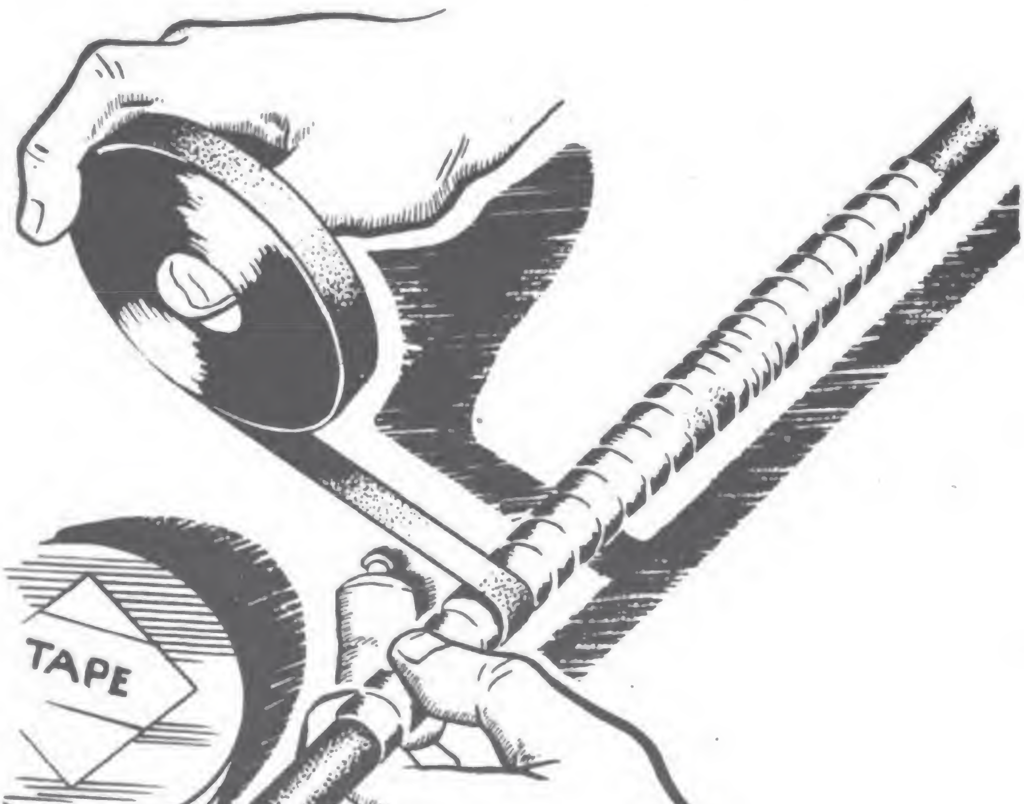


Figure 29.—Applying friction tape.

When you apply friction tape to the splice, you start slightly back of the original braid covering. Figure 29 shows the beginning of a taping job. Wind the friction tape so that each turn

overlaps the one before it. When you get to the other end of the splice, be sure the tape extends over the edge of the braid. Then reverse your direction and wrap a second layer on until you reach your starting point. Cutting the tape and firmly pressing down the end completes your job. If you have done it right, you have a splice which can take as much abuse as the rest of the wire.

When you splice weatherproof wire, you might be working with wire that has no rubber insulation but just a braid covering. In that case you will only have to apply friction tape. No rubber tape is necessary.

Tapped splices require a little more care in taping than butted joints. You must not only completely cover the main wire, but also the branch which is tapped into it. Look at figure 30.

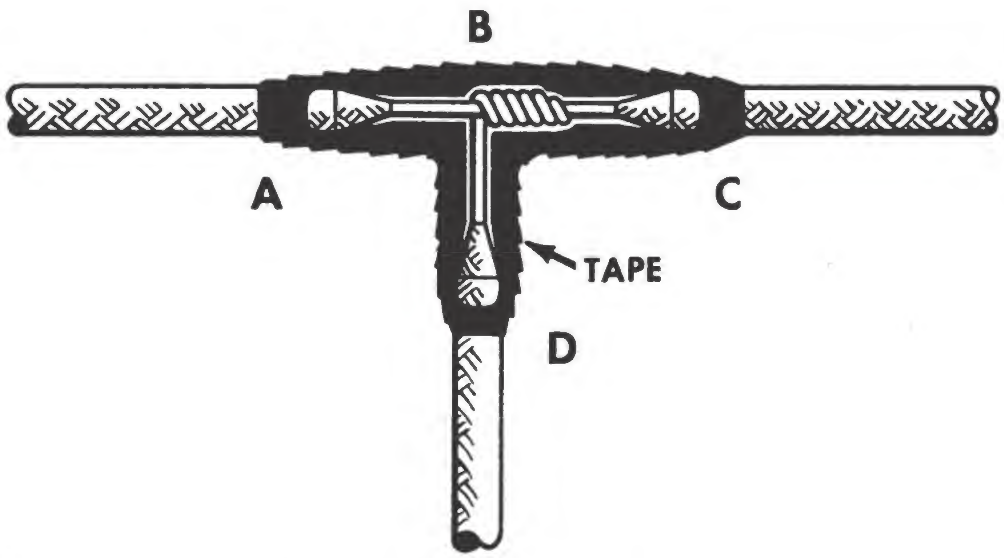


Figure 30.—Wrapping a tapped splice.

It shows that knotted tap splice with which you are familiar. The best way to tape this kind of splice is to start out at point *A* and wrap a layer of rubber tape the full length of the main wire to *C*. Here you reverse your direction and come back to point *B*. When you reach *B*, start wrapping the tape down the branch wire to point *D*. Then return to the main wire at *B*, and complete the taping by wrapping the main wire from *B*

back to A. You apply the friction tape in the same manner as the rubber tape.

Taping a rat-tail joint also requires some care. Just be sure that all parts of the splice are completely covered. That, of course, goes for all the rest of the splices you wrap. If you keep your wraps tight and neat and don't use more tape than is necessary, you will always turn out a good job.

SOLDERLESS CONNECTORS

In the splicing that you read about above, the wires were twisted together to prevent them from pulling apart. They were then soldered to increase their resistance to corrosion.

A quicker and easier way to join conductors together is to use a solderless connector. A SOLDERLESS CONNECTOR uses pressure to keep the wires together. It grips the wires like a vise, producing such good metal-to-metal contact that it is unnecessary to use solder. All you have to do is apply the connector to the wires, and then cover the joint with tape. Of course, you must prepare the wire ends just as you would for a soldered splice.

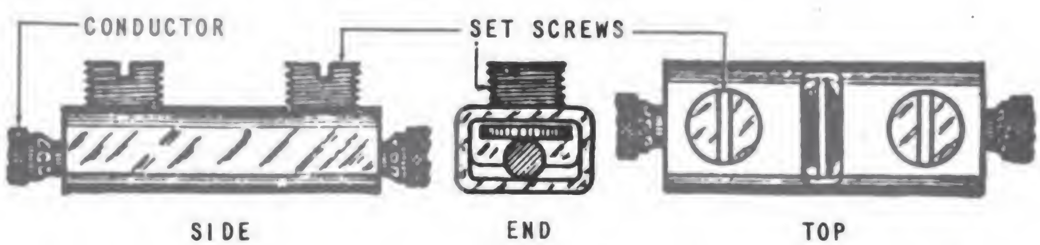


Figure 31.—Using a solderless connector.

Figure 31 gives you a clear picture of one type of solderless connector. You make the connection by inserting the wires into the open ends of the connector and then clamp them down by turning the set screws. If you'll look at the end view of the connector, you will see that the set screw has a wide, flat base. It provides good contact and keeps the wire in a steady position. After you have securely clamped the wires together, you finish the job with a wrapping of rubber and friction tape.

Although there are other types of solderless connectors, they ALL operate on the principle of gripping or pressing the conductors. They save time and provide as high a mechanical strength as soldered splices. If they are available to you, use them!

SUMMARY

Stranded conductors are used for their flexibility. They are made in the larger sizes of cable.

Wires and cables are commonly insulated with rubber. Varnished cambric, asbestos, paper, silk, cotton, and enamel are also employed as insulation where required.

Abrasion, wear, chemical action, and moisture are the enemies of wires and cables. Fibrous braids, lead sheath, and metallic armors, or combinations of each, are used as protective coverings.

The size of a conductor is based on its diameter in mils or its cross-sectional area in circular mils.

The American wire gage (AWG) is the standard measure for all conductors.

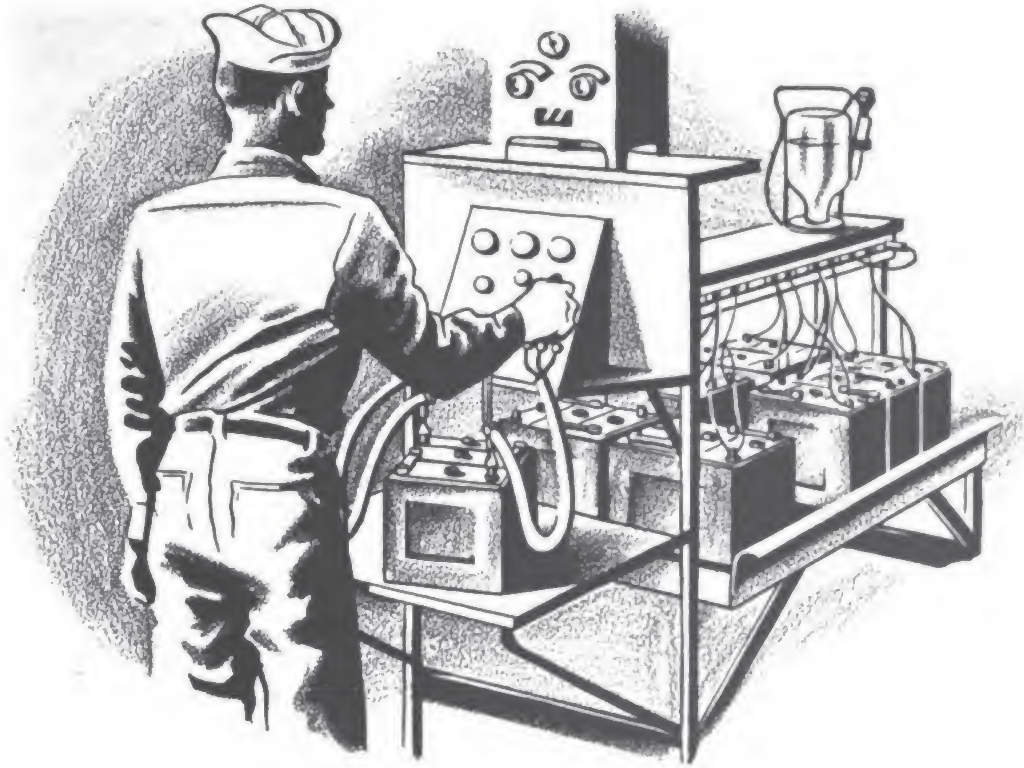
Conductors may be joined together by splicing and soldering, or by the use of solderless connectors.

A good splice must have both mechanical strength and good electrical conductivity.

A wire that has been spliced must have its insulation and protective covering replaced. Rubber tape is used for insulation, and friction tape for protection.

QUIZ

1. What is a conductor?
2. What is the most common material used for conductors?
3. Give two classifications for conductors. Explain the difference between them.
4. Name six common types of insulation used on conductors.
5. Give three different types of protective covering used for wires or cables.
6. What does AWG stand for?
7. Which wire is the largest, No. 14 or No. 4?
8. How strong should a splice be?
9. What kind of metallic coating is found between the copper wire and the rubber insulation?
10. Name five different types of splices.
11. What is meant by tapping a conductor?
12. What is meant by "tinning"?
13. Give three different methods of applying heat to conductors in order to solder them together.
14. Name two different types of tape used to wrap a splice.
15. What is a pressure connector?



CHAPTER 3

BATTERIES

PRIMARY CELL VS. SECONDARY CELL

You're all squared away on conductors. You know that they're made of metal, are insulated, protected, and provide an easy path for current. But what about the current itself? Do you know what it is and what forces it along the wire? If you've read *Electricity*, NavPers 10622, the answers come easy. Current is just the drift of electrons along a wire. The electrons move because an ELECTROMOTIVE FORCE (e.m.f.) pushes them along.

Electromotive force isn't something you pick out of thin air. It's produced only when mechanical, frictional, heat, or chemical energy is converted to electrical energy. Mechanical energy changes to electrical energy when a coil turns in a magnetic field—it's the principle which electric generators operate on. Frictional energy changes to electrical energy when you walk on a soft rug—touching a grounded object produces a

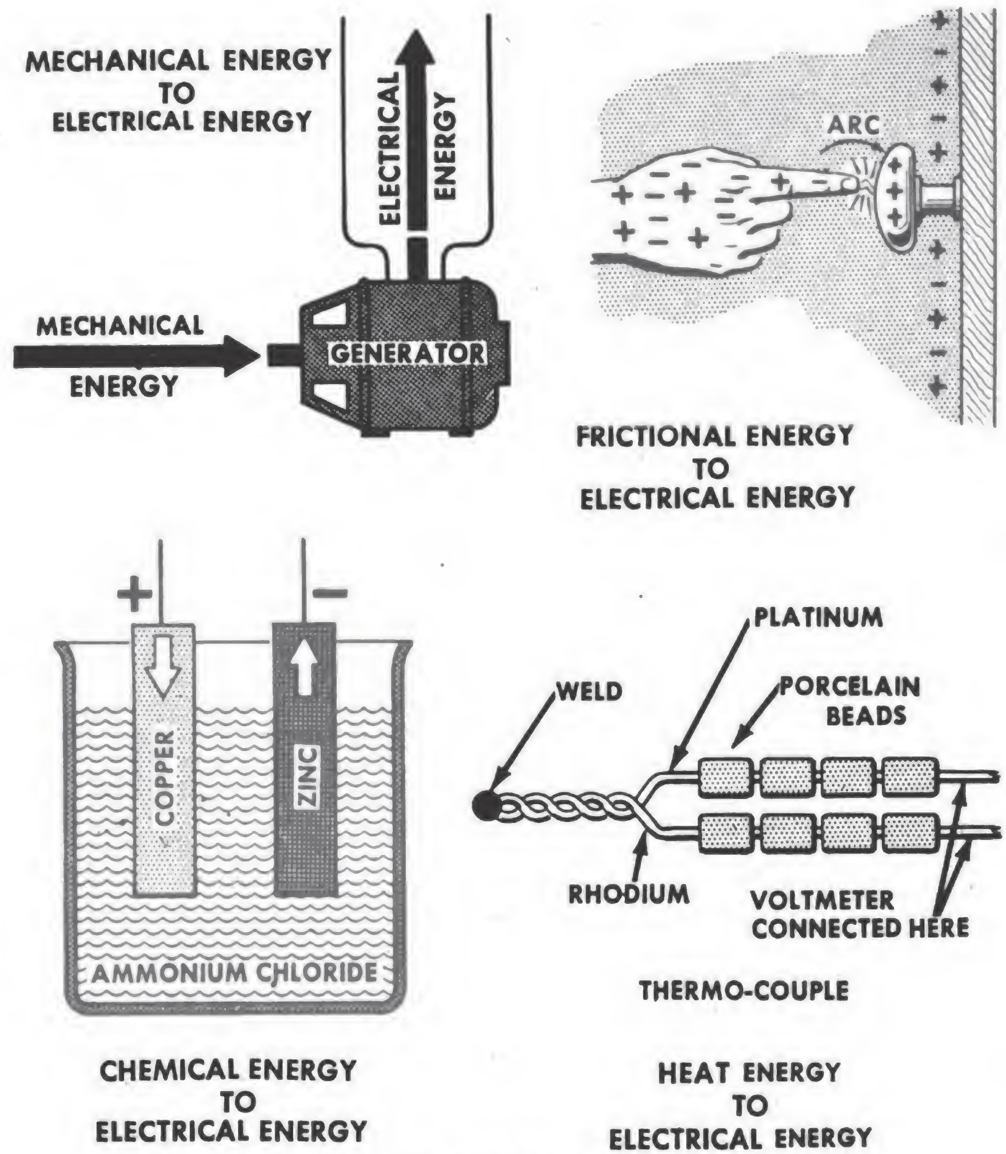


Figure 32.—Four methods of obtaining electrical energy.

spark. Heat energy changes to electrical energy when the ends of two different metals are TWISTED TOGETHER and heated—a small voltage may be measured between their open ends. Chemical energy changes to electrical energy when two unlike metals are placed APART in a chemical solution. An e.m.f. is developed at the external ends of the metal rods. Figure 32 shows these four methods of obtaining electrical energy.

Two unlike electrodes in a chemical solution is just a long way of saying CELL. You may be more familiar with the word "battery" than the word "cell." A BATTERY IS TWO OR MORE

CELLS CONNECTED TOGETHER. The types of electrodes used in the cell will determine its e.m.f. When CARBON and ZINC form a cell they produce an e.m.f. of 1.5 volts. LEAD and LEAD PEROXIDE, on the other hand, generate a voltage of 2.1 volts.

	Type of Electrodes	Type of Service	E.M.F. Per Cell	Uses
PRIMARY CELL (Dry Cell)	Carbon(+) Zinc (−)	Intermittent	1.5 volts	Portable equipment
SECONDARY CELL (Storage Battery)	Lead-peroxide(+) Lead(−)	Continuous	2.1 volts	Semi-portable or stationary equipment

Figure 33.—Primary cell vs. secondary cell.

Carbon and zinc are used in DRY CELLS. Lead and lead peroxide make up a STORAGE BATTERY. You refer to a dry cell as a PRIMARY CELL. A storage battery consists of one or more SECONDARY CELLS. When the dry cell loses its strength you simply throw it away and install a new one. But when the storage battery refuses to give further service, you give it new zip and life by recharging.

The dry cell is small, and thus has the advantage of being very light and portable. Because of its size, however, it can't deliver a large amount of current for any great length of time. It can only be used for short, periodic service. On the other hand, the storage battery produces high current flow for a great length of time. But you can't get something for nothing. High current flow in a storage battery can only be obtained by the use of large amounts of lead. Because lead is heavy and bulky a storage battery usually remains in one spot.

You should be familiar with the whys and wherefores of the dry cell and storage battery. What makes them tick is fully covered in *Electricity*, NavPers 10622. The THEORY of their operation, therefore, will not be discussed here. Check back to NavPers 10622 if you're a little hazy on battery principles.

MEET THE DRY CELL

Uses

When that flashlight of yours refused to give any more light you knew what to do. It was a simple operation to replace the worn out dry cells with new ones. Producing power for flashlights, however, is just one of the jobs of the dry cell. You will

Figure 34.—Equipment powered by the dry cell.

find it used wherever portable electrical equipment must be powered with direct current. Portable transmitters and receivers, such as the walkie-talkie, use dry cell batteries. Field telephones, testing instruments, and field switchboards are

other equipment which take electrical energy from the dry cell. Figure 34 gives you an idea of what this equipment looks like.

Construction

The dry cell is made in various shapes and sizes. It may vary from the small, round flashlight dry cell to the large rectangular switchboard battery. Basically, however, its parts are the same. All DRY CELLS consist of a carbon rod placed inside a zinc container. The container is filled with a moist paste of ammonium chloride. The ammonium chloride is called an ELECTROLYTE. Its job is to produce electrical energy by chemical action. It also provides a path for the electron flow between the zinc and carbon. Figure 35 shows you the inside view of a dry cell.

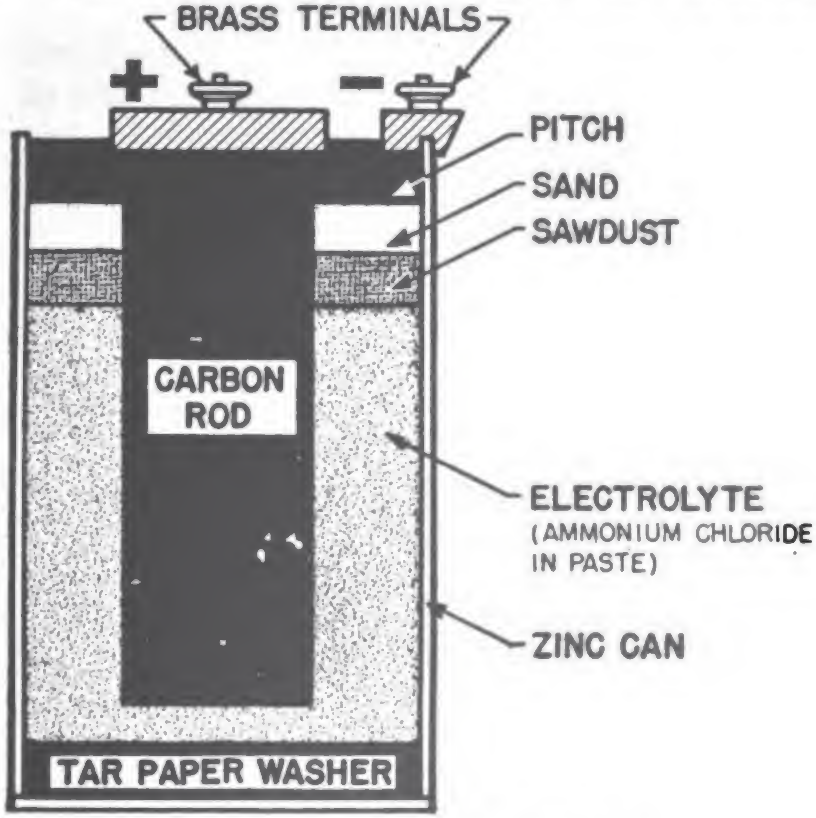


Figure 35.—Inside view of a dry cell.

Notice that the carbon rod is the positive electrode and the zinc can is the negative electrode. In most cases you'll find the terminal of the dry cell—or dry battery—marked with a plus (+) and minus (−) sign to identify the positive and negative terminals. You can't go wrong with your connections if you'll

just remember that the center terminal is always positive and the side terminal always negative.

Installation

There's one thing you should be sure of before you go any further. ALL DRY BATTERIES, NO MATTER WHAT THEIR SIZE, ARE COMPOSED OF INDIVIDUAL 1.5-VOLT DRY CELLS. For example, if you were to remove the outside cover from a 15-volt dry battery, you would find ten 1.5-volt dry cells inside. The cells are connected in SERIES with each other, of course. The negative terminal of one cell is connected to the positive terminal of another cell, which has its negative terminal connected to the positive terminal of the cell next to it. This process of connecting "plus to minus to plus" is completed when all ten cells are connected together in series. A plus and minus lead are then brought through the top of the battery and connected to its positive and negative terminals as shown in figure 36.

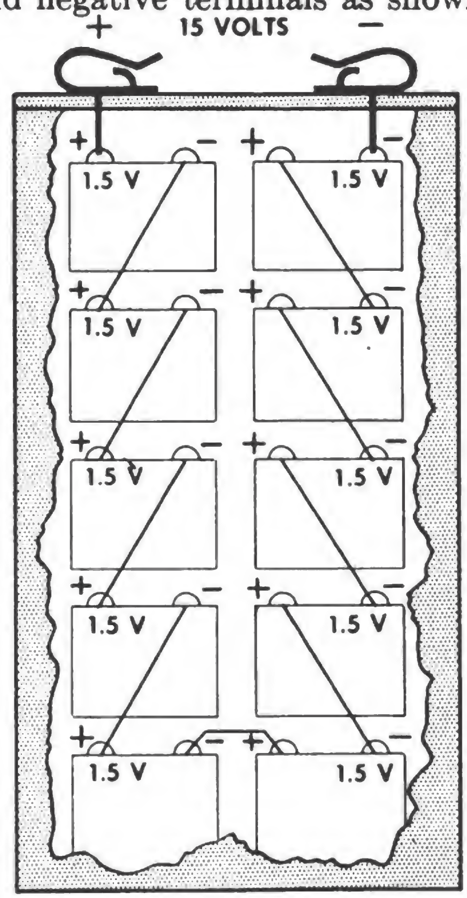


Figure 36.—Construction of a 15-volt battery.

Determining the number of cells that must be connected in series to give a full battery voltage is simple. You know that connecting batteries in series means ADDING their voltages. Thus, should you need an 18-volt battery you would connect twelve 1.5-volt cells in series.

Mark this down in your little black book—it's important! WHATEVER THE SIZE OF EACH PRIMARY CELL, ITS VOLTAGE IS NEVER GREATER THAN 1.5 VOLTS. If you could build a dry cell as large as a cruiser, the cell would only have a terminal voltage of 1.5 volts, the same as the ordinary flashlight dry cell. That's

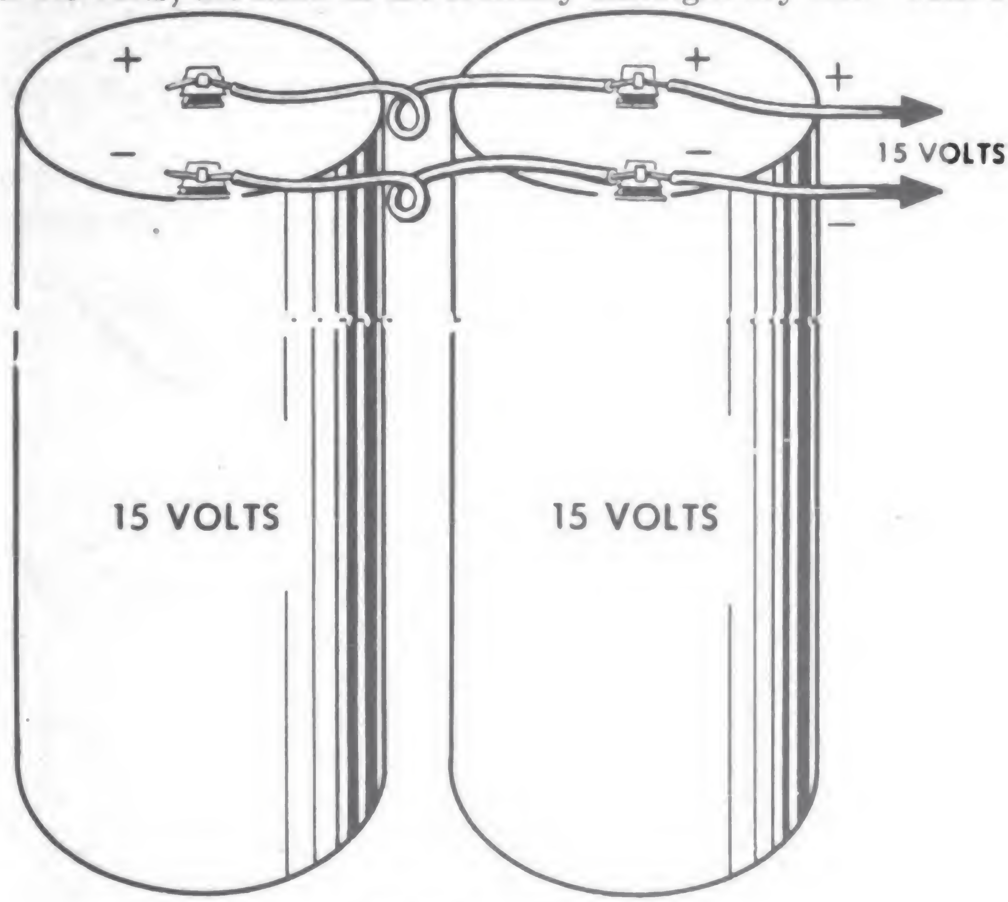


Figure 37.—Batteries in parallel.

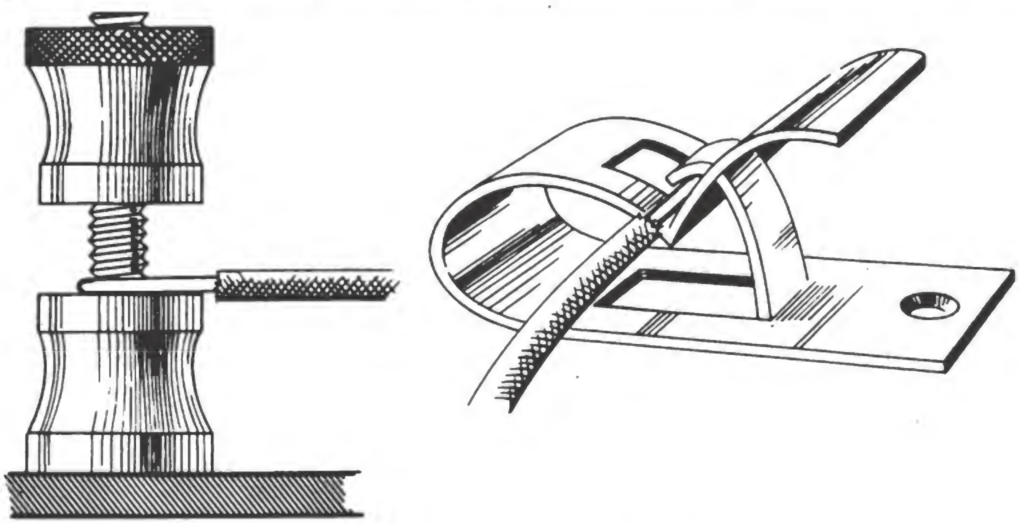
why you must connect cells in series if you want to obtain greater voltages.

You obtain one chief advantage by increasing the size of a dry cell. That advantage is GREATER CURRENT DRAIN FOR A LONGER TIME. When you increase the size of a battery you are increasing the AREA of its electrodes. The greater the area of

the carbon and zinc electrodes, the longer they will last. Naturally, you can't build a dry cell to any size you wish. The batteries you work with have been made up of definite-sized cells. But you can get longer life from a battery without changing its physical dimensions. All you have to do is add another battery of the same voltage, in PARALLEL.

Putting batteries in parallel means connecting positive terminals to positive terminals and negative terminals to negative terminals. Common sense will tell you that two 15-volt batteries in parallel will last longer than only one 15-volt battery—in fact, twice as long. Check figure 37 for the correct picture of batteries in parallel. Notice that the output voltage is still 15 volts.

When you install dry cell batteries you must observe two precautions. First, be sure that your battery has the correct



SCREW-POST TERMINAL FAHNESTOCK CLIP

Figure 38.—Battery terminal posts.

voltage required by the equipment it serves. Usually each piece of equipment uses a specially designed battery. However, you might find yourself in a situation where you have to obtain a definite voltage from whatever batteries you have on hand. Just put your knowledge of series and parallel connections to work and you're all set.

The second precaution you must observe is to see that you have clean and tight connections at the battery terminal posts.

The wires which connect from battery to battery, or from battery to equipment, are the paths over which the electrons travel. If they are loose or improperly cleaned, you're in for trouble. The wires are usually fastened at the terminal posts by either a brass post and nut or a Fahnestock clip. Figure 38 shows you these two types of fasteners, and the correct way to attach the leads. When you use the post and nut, make sure the wire is hooked around the post in the same direction in which the nut

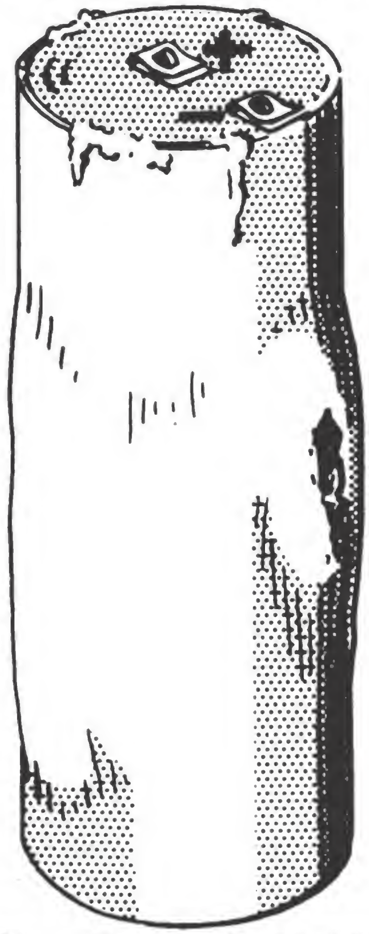


Figure 39.—Visual inspection.

tightens. Before the wire is attached, of course, its end must be stripped of insulation and the exposed conductors scraped clean.

Maintenance

After you install the dry battery, don't sit back and relax. You still have a job to do. That job is keeping a check on the battery while it is working in the circuit. As the battery sup-

plies electrical energy, its composition is continually changing. This change is due to a chemical action which gradually eats away the carbon and zinc electrodes. This shows up both in the external appearance of the battery and in the value of its terminal voltage.

Checking the external appearance of the battery is called VISUAL INSPECTION. If the battery is supplying a large amount of current it will tend to heat up. This heat will cause gases to collect inside the battery. You'll notice the result on the outside by a bulging of the battery case. If this bulging is allowed to continue, the case will crack and spill the acid paste electrolyte over the equipment. Sometimes the zinc container will be eaten away to the point where it too will allow the electrolyte to escape. You can check this by looking for a whitish substance on the outside of the battery. If you find it, pull that battery immediately and replace it with a new one.

You can't always tell if a battery is bad by visual inspection. A poor battery may LOOK as perfect as a good one. Checking the voltage of the battery with a VOLTMETER is your best indication of battery condition.

Never check the voltage of a battery when it is not connected to the circuit. It isn't a good indication of the battery's worth. A battery actually has two voltages. One is called OPEN CIRCUIT or INTERNAL voltage and the other TERMINAL voltage. The open circuit voltage of a battery is the voltage measured across its terminals BEFORE it is placed in the circuit. The terminal voltage is the voltage measured across the battery's terminals AFTER it has been placed in the circuit.

The terminal voltage of a battery is always LESS than the open circuit voltage. Figure 40 shows you why. When you check the open circuit voltage, no current is flowing through the battery, and you simply get the battery's e.m.f. When you check the terminal voltage, you obtain the difference between the battery's e.m.f. and the voltage drop within the battery itself. The voltage drop in the battery is the result of current flowing through the electrolyte from the zinc to the carbon electrode. The electrolyte has a definite resistance. As the battery ages, the electrolyte's resistance increases. This

results in a greater internal voltage drop. Thus, you will find the battery's terminal voltage decreasing as the battery ages.

When you use a voltmeter to check a battery, keep the following in mind:

1. The battery under test should remain in the circuit.
2. Use a high-resistance voltmeter to obtain a true reading.
3. Be sure you use a direct-current voltmeter.
4. Connect the positive terminal of the meter to the positive terminal of the battery. Do the same with the negative terminals.

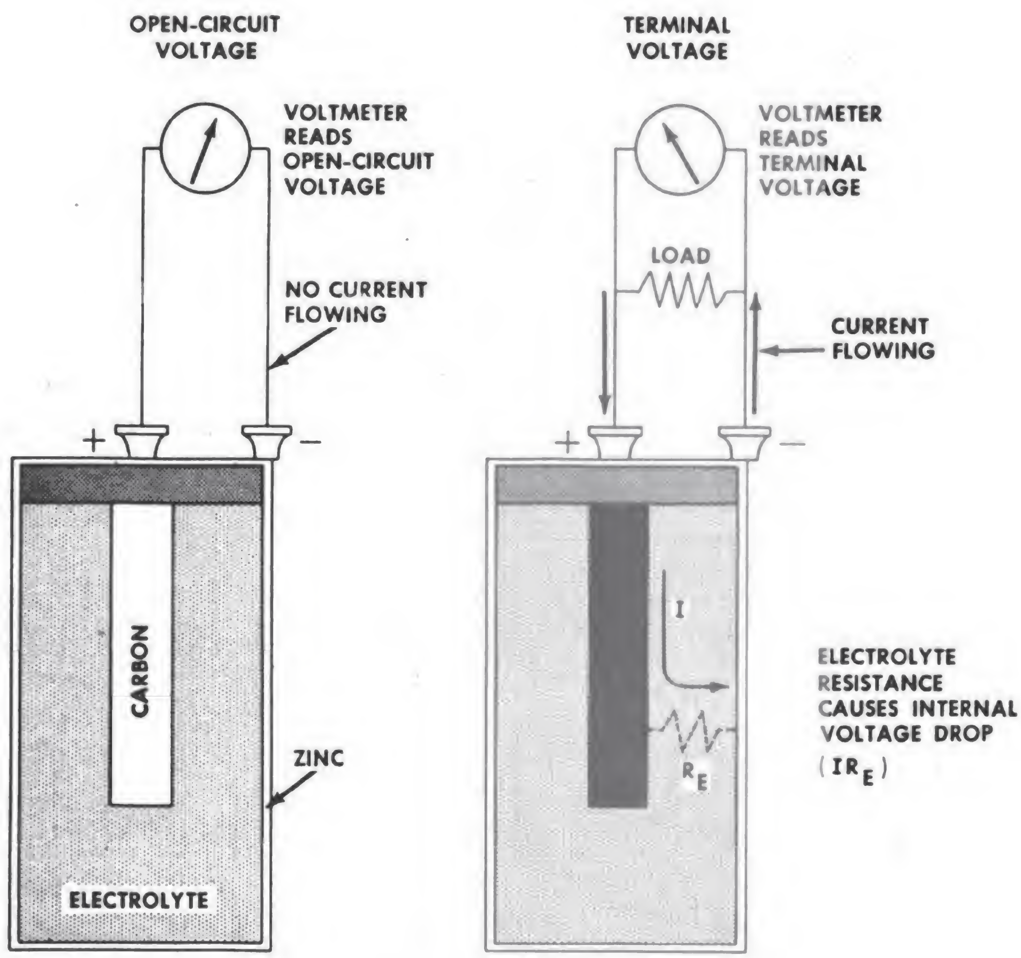


Figure 40.—Terminal voltage and open circuit voltage.

MEET THE STORAGE BATTERY

Uses

A storage battery plays the same part in an electrical system as a water tank plays in a water system. Each acts as a reservoir or storage place. The water tank stores water which can be released when the need arises. The battery stores electrical energy in chemical form which can also be drawn away, or DISCHARGED, when needed. The water tank can be refilled during its idle periods. When the battery is not being discharged, its energy can also be restored by RECHARGING.

Wherever you have equipment in need of steady direct current and reserve power, you'll find the storage battery. Diesel generators have to get rolling before they'll deliver any current. The storage battery and the starting engine team up to do the job. The central office, which is the brains of a telephone system, must have a reliable power source to run its switchboards. The storage battery fills the bill here, too.

Construction

If you had to describe the construction of the storage battery you would begin with the battery CONTAINER. You would explain that the container is a one-piece affair, molded of hard rubber, and divided into compartments or CELLS. Each cell is a basic unit, and when fully charged develops an e.m.f. of 2.1 volts. When the cells are connected in series, they produce

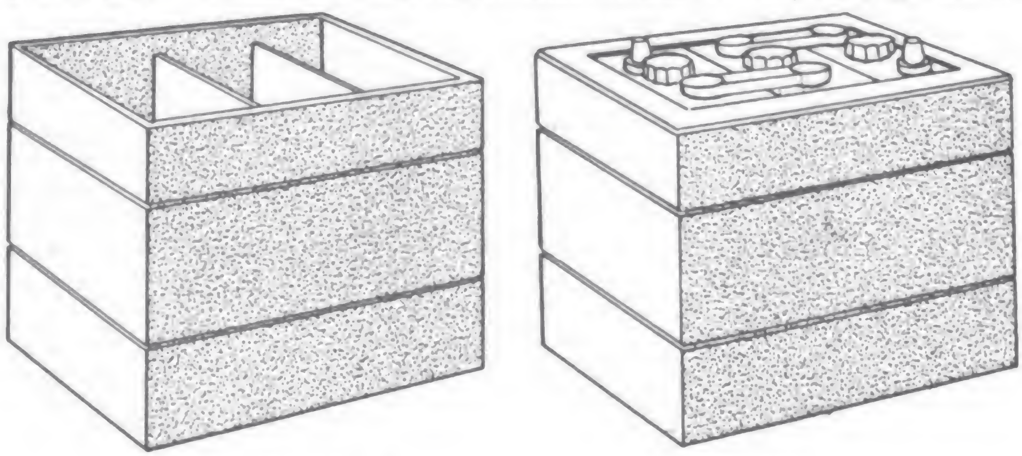


Figure 41.—Empty and full compartments of a battery container.

a total battery voltage which is the sum of all their e.m.f's. The number of cells which a battery contains depends, of course, on the job it has to do. Figure 41 will help your explanation along. It shows a battery container, with both empty and filled compartments. This particular battery has three cells. Its total voltage, therefore, would be about 6.3 volts.

What is put into each cell to generate that 2.1 volts? Well, you know what the basic components must be. Just two different electrodes in an electrolyte will do the trick. The cell of the storage battery uses lead and lead peroxide as its electrodes and sulfuric acid as its electrolyte.

Negative and Positive Plates

Lead and lead peroxide are soft and weak. They would break down under their own weight if formed directly into

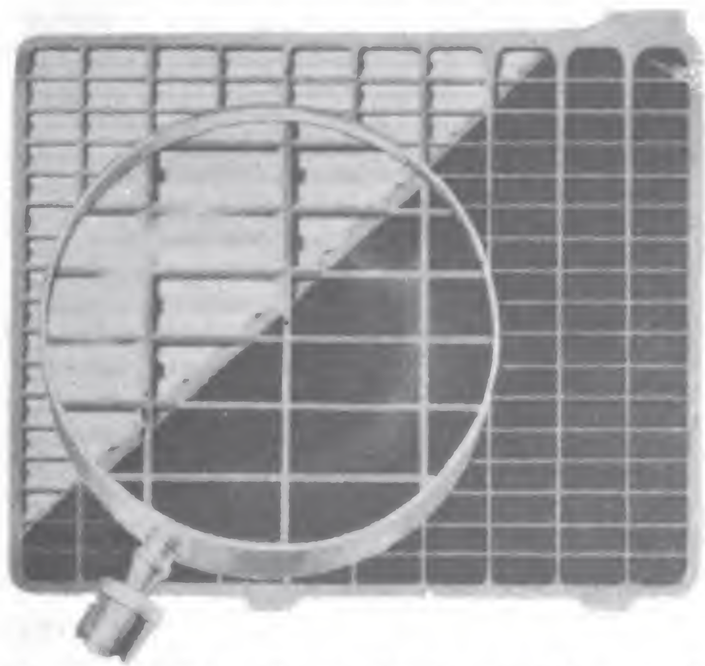


Figure 42.—Plate with part of active material removed.

electrodes. That's why a grid framework of stiff metal is used as a support. The lead and lead peroxide are pasted into spaces of the framework and dried. The lead then forms a NEGATIVE PLATE. The lead peroxide forms a POSITIVE PLATE. Figure 42 shows you what a plate looks like. Only half the plate is filled so you can see its grid structure. The

plate is rectangular in shape to allow it to fit inside the cell compartment.

The cell of a storage battery does not contain just a single positive and negative plate for its electrodes. If you were to use only one negative and one positive plate, the life of the cell would be very short. The areas of the plates determine how long they last. Of course, you could increase the size of the plates, but that would mean increasing the size of the cell. There's a much simpler way. Suppose you took five small negative plates, spaced one behind the other, and connected them together. You would then have a negative electrode with

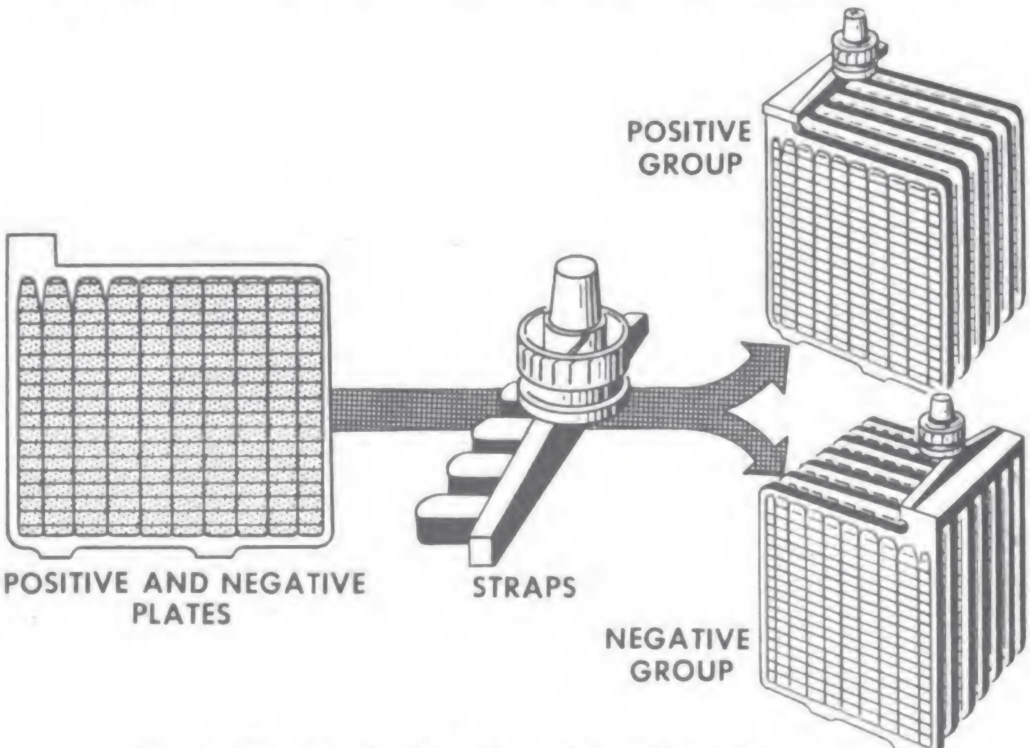


Figure 43.—Construction of positive and negative groups.

a surface area five times that of a single plate. The positive plate's area can be increased in the same manner.

Negative and Positive Groups

When you combine negative plates you form a NEGATIVE GROUP. Positive plates connected together form a POSITIVE GROUP. Construction of a positive and negative group is shown in figure 43. Each plate has a piece of metal, or lug, extending from a top corner. The plates of each group are fastened to-

gether by welding their lugs into the evenly spaced slots of a bar of lead. The bar of lead is known as a PLATE STRAP. Each plate strap has a round terminal post which serves as an outside connection after the cell has been sealed. The post of the positive group plate strap becomes the positive terminal of the cell. The post of the negative group plate strap becomes the negative terminal.

A positive plate must face a negative plate to get battery action. To obtain this effect the negative group is interlaced with a positive group as shown in figure 44.

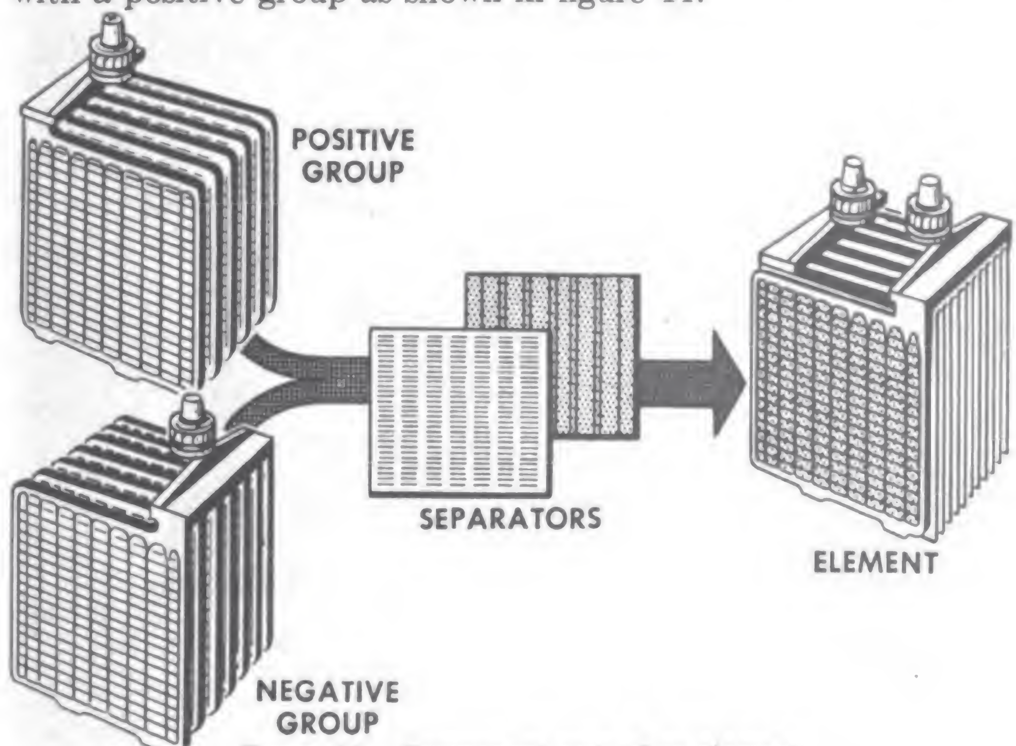


Figure 44.—Component parts of an element.

Check closely and you'll notice that the negative group has one plate more than the positive group. This gives both sides of a positive plate a negative plate to interact with.

You can see that the negative and positive plates of each group are very close to each other. If any one negative plate should touch a positive plate, your cell action would stop. In fact, you would have a short on your hands. This is prevented by placing an INSULATOR between each plate.

The INSULATOR must have three qualities. It must be thin, of course, to fit into the narrow spaces. It must be porous to

allow the electrolyte to circulate between the positive and negative plates. And it must be able to withstand the chemical action of the electrolyte. Certain types of wood and rubber will meet these requirements. They come in thin sheets which are smooth on one side and grooved on the other. When the separator is placed between the plates, its grooved side faces the positive plate. Figure 44 shows you the back and front view of a separator. After all the separators have been placed between the plates, your complete assembly becomes an ELEMENT. This is also shown in figure 44.

The number of elements a battery uses, depends on the num-

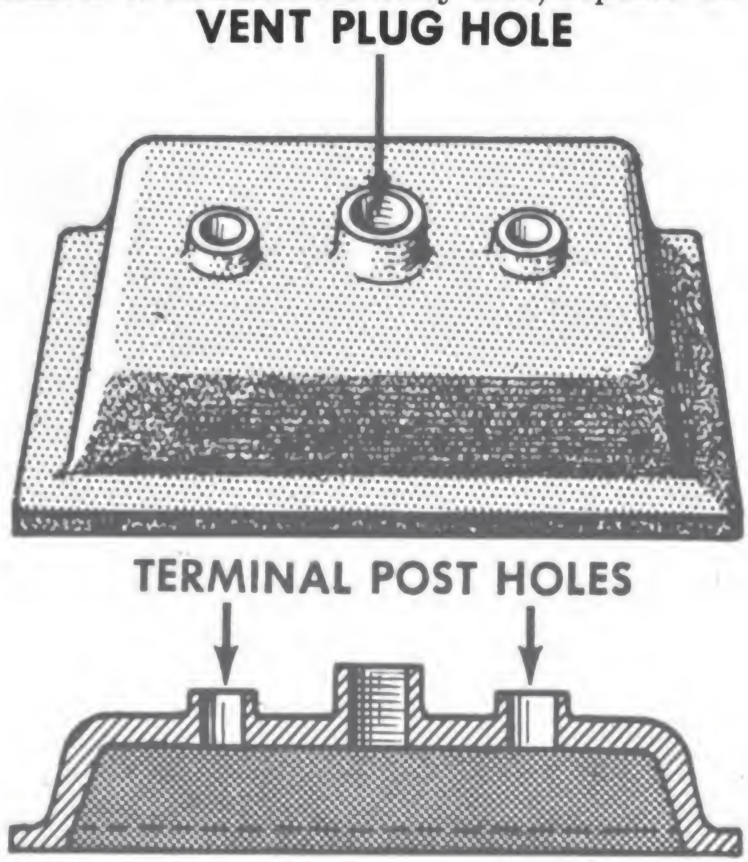


Figure 45.—Typical cell cover.

ber of cells it has. The three-cell battery shown in figure 37 has three elements—an element for each cell. A 12-volt battery (6 cells) would have six elements.

Cell Cover

Suppose you were to place an element in an open cell, filled

with electrolyte. Would it generate a voltage of 2.1 volts? Yes—but not for long! Just let a little dirt fall into the cell and its voltage drops. A cell should contain only the element and electrolyte. That means you must place a cover over the cell and seal it completely.

The top and side view of a typical CELL COVER is shown in figure 45. It is made of material which resists acid. The two end holes are the ones through which the terminal posts fit. The hole in the center of the cover serves two purposes. It provides you with an opening to test or inspect the cell's condition. It also allows you to add water to the cell. When not being used for these purposes, the center hole is fitted with a VENT PLUG. The vent plug has one small hole through it. The hole is too small to let dirt in, but does offer an avenue of escape to any gases which accumulate in the cell. The cell cover is sealed to the top of the cell by the use of a pitch compound. Figure 46 is a cross-sectional view of a cell cover in position.

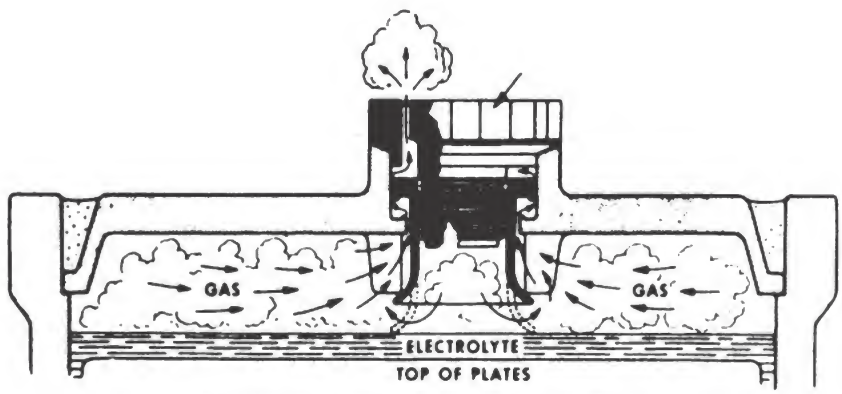


Figure 46.—Cell cover in position.

Cell Connectors

You now have the elements in their cells and the cell covers securely in place. Your storage battery is almost complete. Now, you need only to connect the cells IN SERIES to obtain the full battery voltage. The positive terminal of the first cell is tied to the negative terminal of the next cell, and so on down the line. You end up with an unconnected positive and an unconnected negative terminal. The full battery voltage is taken from these terminals.

You could use jumper wires as connectors, but they wouldn't last very long. A battery takes a lot of abuse. That's why you'll find strong, sturdy CELL CONNECTORS used. A cell connector is just a short, straight lead bar. It has two holes on either end to fit over the terminal posts. A low resistance connection is made by actually fusing the connector to the terminal posts. A picture of the cell connector is shown in figure 47. The same figure also shows you the completed battery. It is the 12-volt type (6 cells).

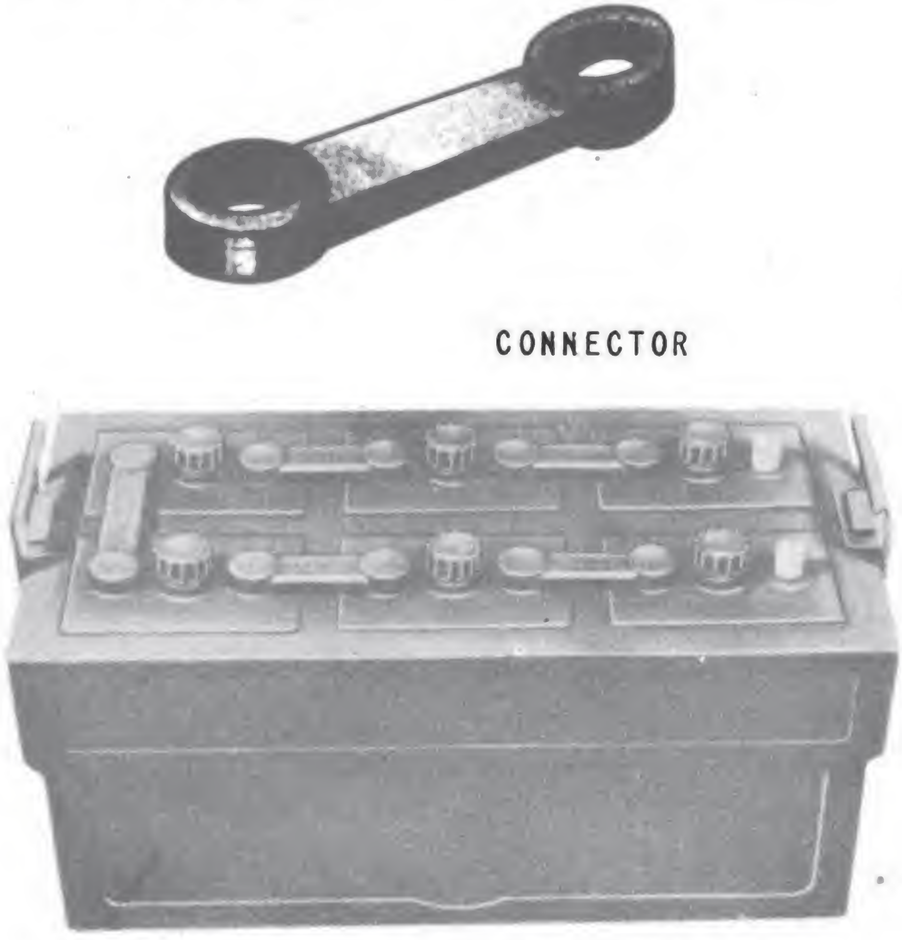


Figure 47.—Cell connector and completed battery.

Figure 48 shows you a 12-volt battery with a cutaway view of a cell compartment. You can actually see the construction of a completed cell. Notice that the plates of the group do not touch the bottom of the cell. Instead, they rest on ridges which form a SEDIMENT SPACE. During the normal life of the battery,

the plates of the positive group shed small pieces of lead peroxide. These particles of active material fall into the sediment space where they can't do any harm. If allowed to build up between the plates, they soon would form a bridge between the positive and negative groups. Then your cell has a dead short.

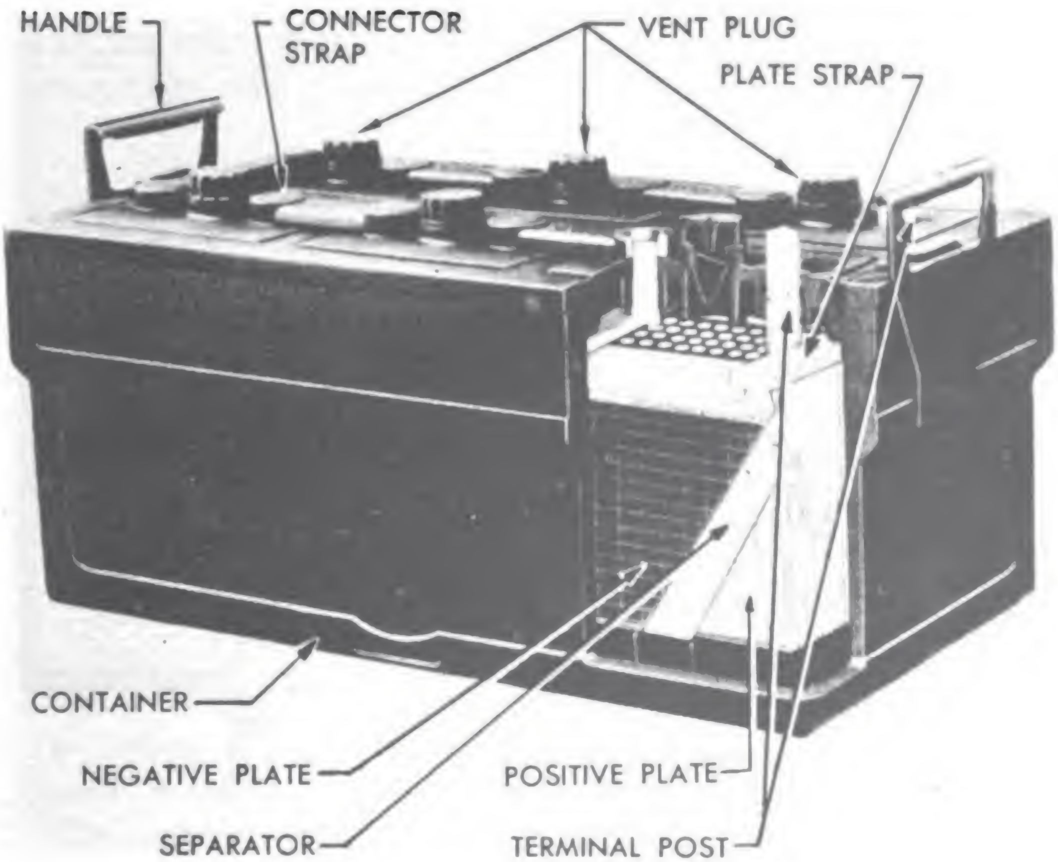


Figure 48.—View of a cell compartment.

Even the separators are constructed so as to aid the falling of sediment. Remember those grooved sides of the separators which faced the positive plates? They provide channels for the particles and direct them downward to the sediment space.

Capacity

It's easy to understand battery capacity if you compare it to water-tank capacity. Suppose you had two water tanks as shown in figure 49. One tank holds 20 gallons of water and the other 40 gallons. The valve of each tank is opened so that each

will deliver water at the SAME RATE. You can see that the larger tank will continue to deliver water long after the small tank is empty—actually, twice as long. You can say that the larger tank has twice the capacity of the smaller one.

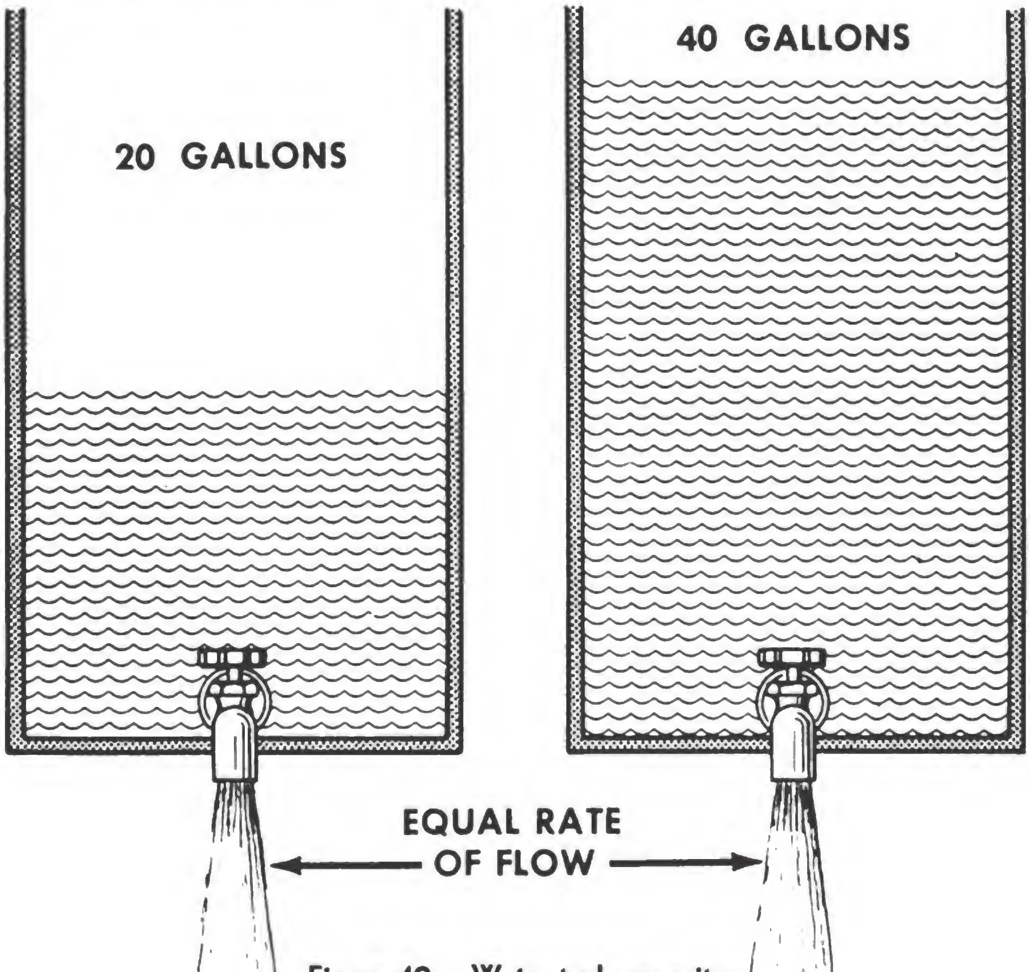


Figure 49.—Water-tank capacity.

Batteries are made in all sizes, too. Figure 50 shows you some various-sized batteries you will work with. Each has a certain CAPACITY. It is measured in AMPERE-HOURS. Like the water tanks, a battery with twice the ampere-hour rating of another battery will last twice as long, if both are discharged at the same rate.

Ampere-hour means current in amperes multiplied by time in hours. If you know the current drain of a piece of equipment, you can pick the right battery for its power source. Suppose you have a telephone switchboard which draws an average cur-

rent of 20 amperes at 24 volts. You also have two 24-volt batteries available as power sources. One battery is rated at 100 ampere-hours and the other at 20 ampere-hours. Both batteries meet the voltage requirements and each can deliver the required current. Your problem is to find which will last the longest before recharging is necessary. The 20-ampere-hour battery will deliver 20 amperes for only one hour (20 amps x 1 hr. = 20 ampere-hours). The 100-ampere-hour battery

Figure 50.—Types of batteries.

will produce 20 amperes for 5 hours (20 amps x 5 hrs. = 100 ampere-hours).

You can see that the 20-ampere-hour battery will require recharging every hour, the 100-ampere-hour battery every 5 hours. You've solved the problem of which battery to use. The 100-ampere-hour battery would naturally be your choice, since it requires the least attention and maintenance.

The ampere-hour rating can be used only when the battery is discharging at a normal rate. It is somewhat difficult to figure how long a battery will last if it is discharged at a high rate. It all ties up with the changes that take place inside the battery during its discharge.

When the electrolyte (sulfuric acid) reacts with the positive plate, it changes into water. A normal discharge rate allows enough time for the water to mix with the remaining electrolyte. The reaction thus continues at an even pace. At a high discharge rate the water is forming so fast that it hasn't time to mix with the remaining electrolyte. When this happens your battery action stops. You can draw a very heavy current, but it only lasts for a short time. Figure 51 gives a clear picture of battery action for normal and high discharge rates.

When a battery has lost its strength because of a short, heavy current drain, it can be used again without recharging. You only have to remove it from the circuit and let it stand idle for a while. This allows the electrolyte to mix with the water that

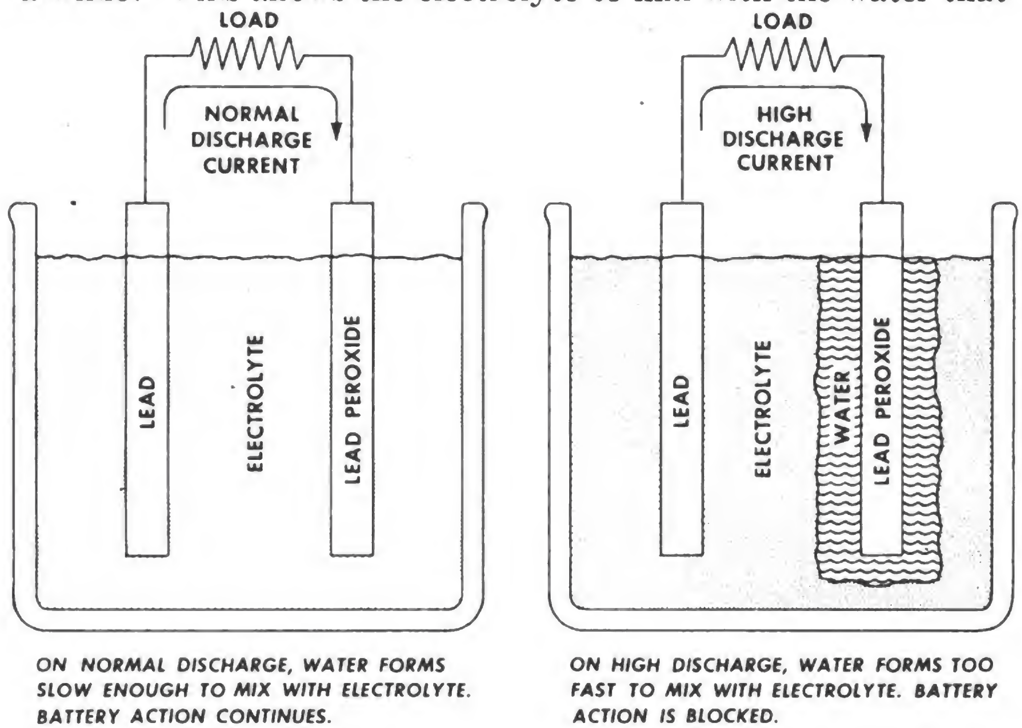


Figure 51.—Effect of normal and high discharge rates.

was formed during its short discharge. When you check the battery's strength you will find it has returned to normal. The battery can then be returned to the circuit.

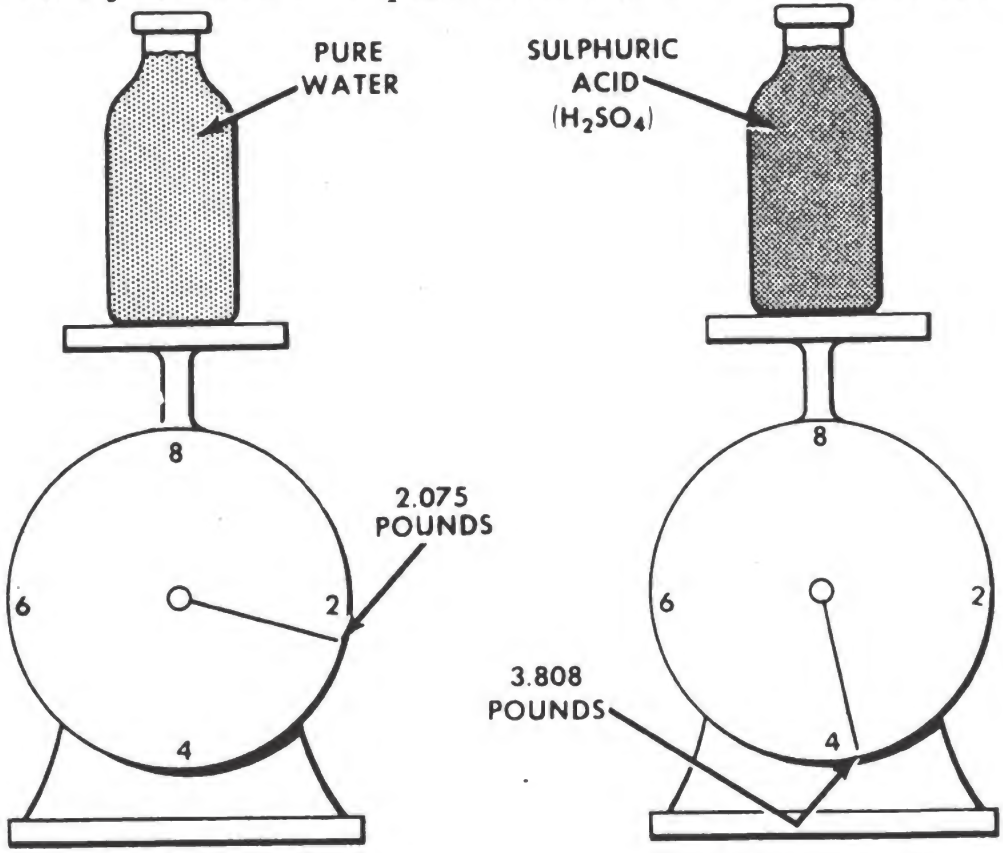
STORAGE BATTERY ELECTROLYTE

Composition

$H_2SO_4+H_2O$ isn't double talk. It's just a short way of saying, "sulfuric acid mixed with water." You know it as the electrolyte used in the storage battery. Without it there wouldn't be any battery action.

The strength of the electrolyte can be measured by its SPECIFIC GRAVITY. The specific gravity of any substance is its weight COMPARED to the weight of an equal volume of pure water.

Suppose you had to determine the specific gravity of the sulfuric acid used in the electrolyte. Figure 52 shows you how to do it. First, you would fill a quart bottle with pure water and weigh it. The scales would show a weight of 2.075 pounds. Then you would fill a quart bottle with the sulfuric acid and



$$\text{SPECIFIC GRAVITY OF } H_2SO_4 = \frac{\text{WEIGHT OF } H_2SO_4}{\text{WEIGHT OF WATER}}$$

$$\text{SPECIFIC GRAVITY OF } H_2SO_4 = \frac{3.808}{2.075}$$

$$\text{SPECIFIC GRAVITY OF } H_2SO_4 = 1.835$$

Figure 52.—Determining specific gravity by comparing weights.

weigh it. The scales would show a weight of 3.808 pounds. You don't have to be a mathematician to see that the sulfuric acid is 1.835 TIMES as heavy as the water. Therefore, the sulfuric acid has a specific gravity of 1.835. Pure water, of course, has a specific gravity of 1.000.

The electrolyte contains both sulfuric acid and water. You

can see that its specific gravity will be less than 1.835 and more than 1.000. Its exact specific gravity depends on the proportions of acid and water used.

Figure 53 is a table which shows you how much water and acid should be mixed together to get a certain specific gravity. For example, an electrolyte of 1.300 specific gravity is made by mixing 5 parts of water to 2 parts of acid—if you start with a 1.835 specific gravity acid. If you have a 1.400 specific gravity acid, you have to use different values. The table indicates 2 parts of water tó 5 parts of acid as the correct proportions to secure 1.300 electrolyte.

Specific Gravity Desired	Using 1.835 Sp. Gr. Acid		Using 1.400 Sp. Gr. Acid	
	Parts of Water	Parts of Acid	Parts of Water	Parts of Acid
1.400	3	2	—	—
1.345	2	1	1	7
1.300	5	2	2	5
1.290	8	3	9	20
1.275	11	4	11	20
1.250	13	4	3	4
1.225	11	3	1	1
1.200	13	3	13	10

Figure 53.—Electrolyte mixing chart.

Mixing the Electrolyte

Batteries aren't always shipped ready for use. Some are received "dry." Before they can be used you must fill them with electrolyte. That means mixing sulfuric acid and water together. The specific gravity of the electrolyte for normal climates should be 1.300, and 1.225 for tropical climates.

Mixing water and sulfuric acid together is a DANGEROUS JOB. You've got to do it right the FIRST time. A pair of burnt dungarees are easy to replace, but you can't buy a new face. FIRST, put the WATER into the container. Then SLOWLY ADD THE ACID TO THE WATER. You'll still generate a lot of heat, but not enough to crack the container. AVOID SPLASHING. If you have rubber gloves, an apron, and goggles handy, wear them! They'll

protect your clothes and eyes from acid splash. Don't use just any old can as a container. Sulfuric acid attacks every metal except lead. So if you want to end up with a clean electrolyte, use a glass, earthenware, or lead container to hold your mixture.

If you do accidentally spill acid on yourself, keep calm and apply first aid. The FIRST thing you should do is DOUSE THE BURNED AREA WITH LARGE AMOUNTS OF WATER. This will remove most of the acid. Then apply a solution of BAKING SODA AND WATER. This will neutralize any acid which remains. Check with the dispensary for further treatment.

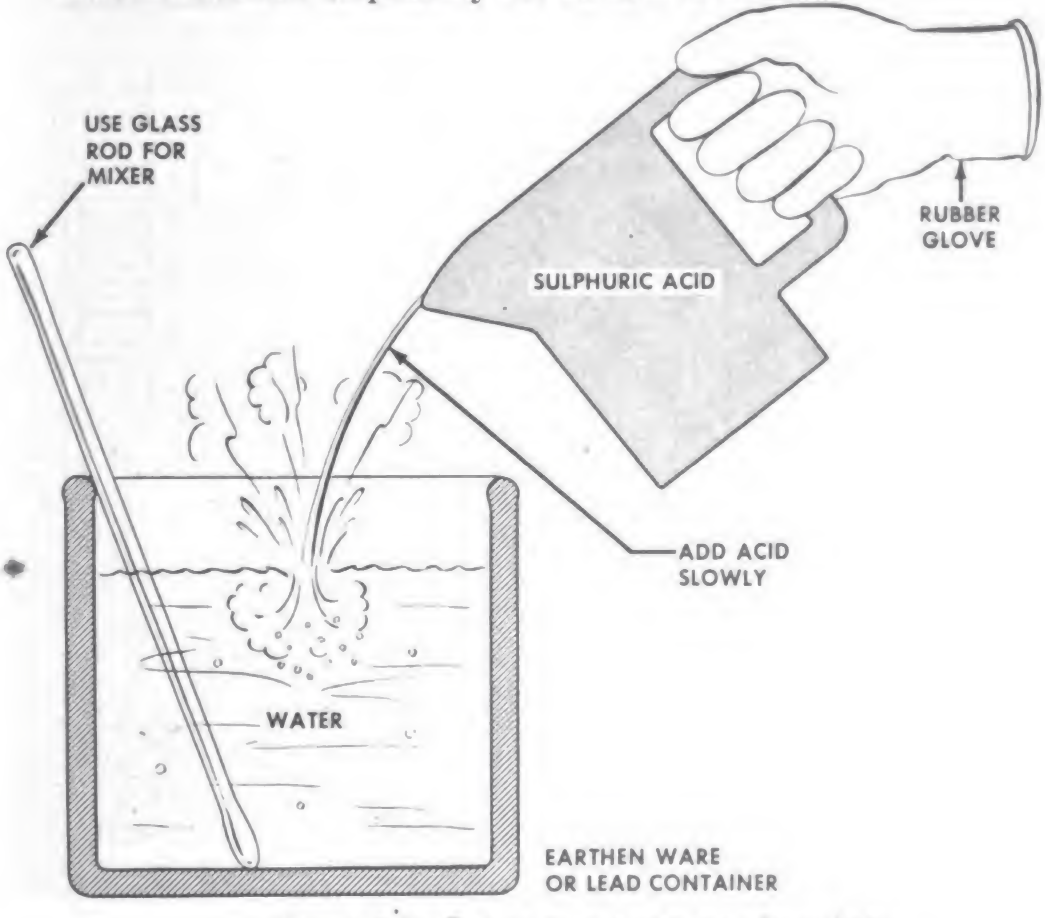


Figure 54.—Proper way to prepare electrolyte.

It's important that you use PURE water for mixing electrolyte. That means water which is free from dirt and minerals. Distilled water is your best bet, but rain water will do in a pinch. Just be sure you collect the rain water in a non-metallic vessel. One last word of caution. After mixing the electrolyte, let it cool to room temperature before adding it to the battery cells.

Hot electrolyte will eat up the cell plates rapidly. To be on the safe side, don't add the electrolyte if its temperature is above 90° F. Figure 54 shows you the proper way to prepare electrolyte.

USING THE HYDROMETER

The specific gravity of the electrolyte is a good indication of battery strength. When the battery is discharging, the electrolyte changes in composition. The sulfuric acid decreases and the water increases. Thus you'll discover that the specific

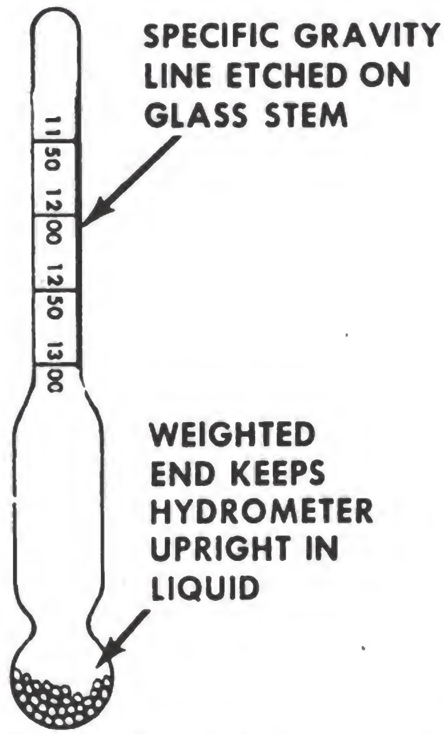


Figure 55.—Construction of the hydrometer.

gravity of the electrolyte will DECREASE. When the battery is being charged, the opposite takes place. The sulfuric acid increases and the water decreases, giving an INCREASE in specific gravity.

Suppose you wanted to determine the condition of your battery. You could draw a little electrolyte from each cell and compare its weight to that of an equal volume of water. But that's the hard way. Using a HYDROMETER is the easy way.

The hydrometer is a slender glass rod as shown in figure 55. It is weighted at the bottom so it will float in an upright position when placed in a liquid. Part of the hydrometer is below the surface of the liquid and part is above. How deep the hydrometer sinks depends on the specific gravity of the liquid.

There are lines etched on the stem of the hydrometer. Each line is marked with a definite value of specific gravity. You

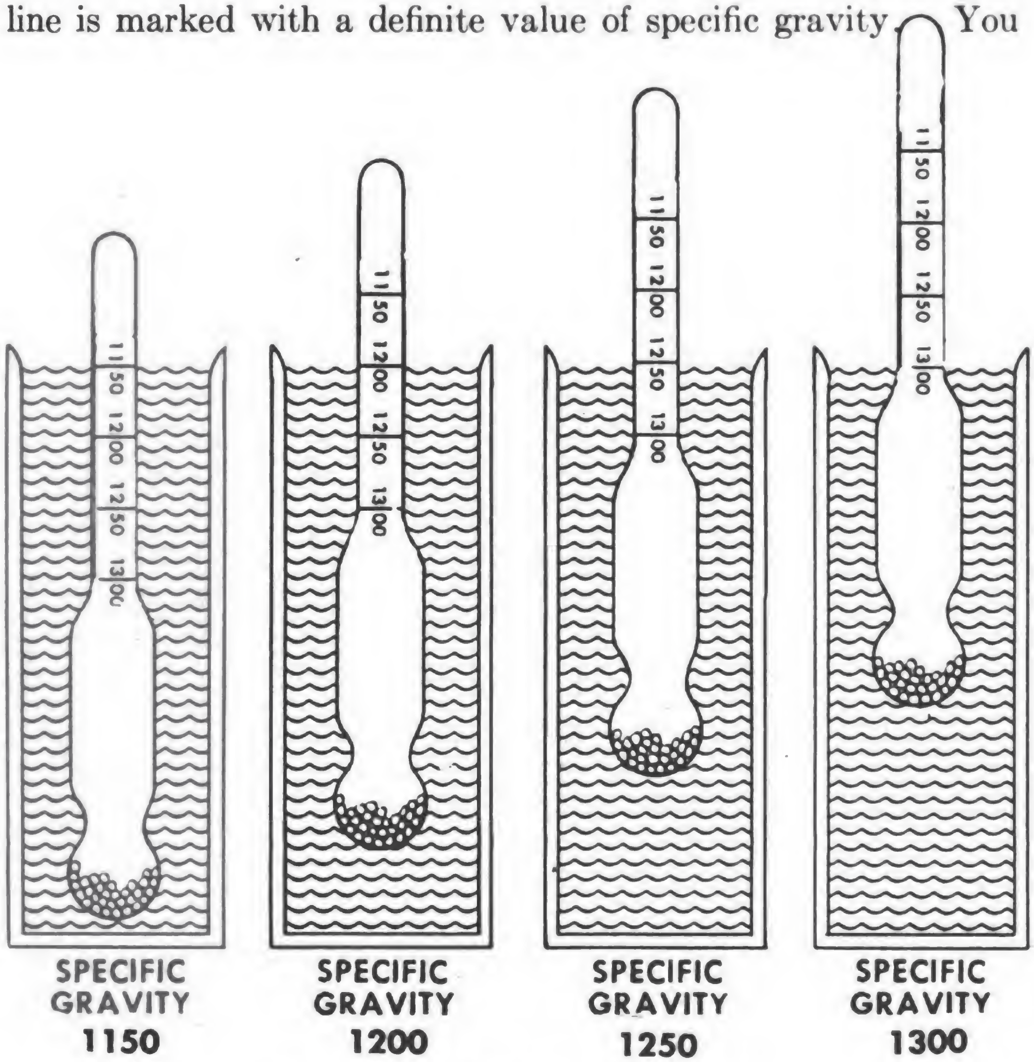


Figure 56.—Reading the hydrometer.

read the specific gravity of the liquid at the point where the surface of the liquid touches the hydrometer stem. Figure 56 shows you the position of the hydrometer in four electrolytes of different strengths. Each has a different specific gravity as indicated by the hydrometer.

Notice the values of specific gravity marked on the hydro-

meters in figure 56. They do not have a decimal point after the first number. It is customary to omit the decimal point when READING specific gravity. Thus, a specific gravity of 1.150 is read as 1150. The decimal point is understood, but is not mentioned.

Since the electrolyte is inside the battery container, you would find it impossible to measure its specific gravity by placing a hydrometer float inside of the cell. There's another way. A sample of the electrolyte is drawn up from the cell by means of a HYDROMETER SYRINGE. The hydrometer syringe is simply a glass barrel with a rubber tube at one end and a rubber bulb at the other. The hydrometer is inside of the glass barrel. This is shown in figure 57.

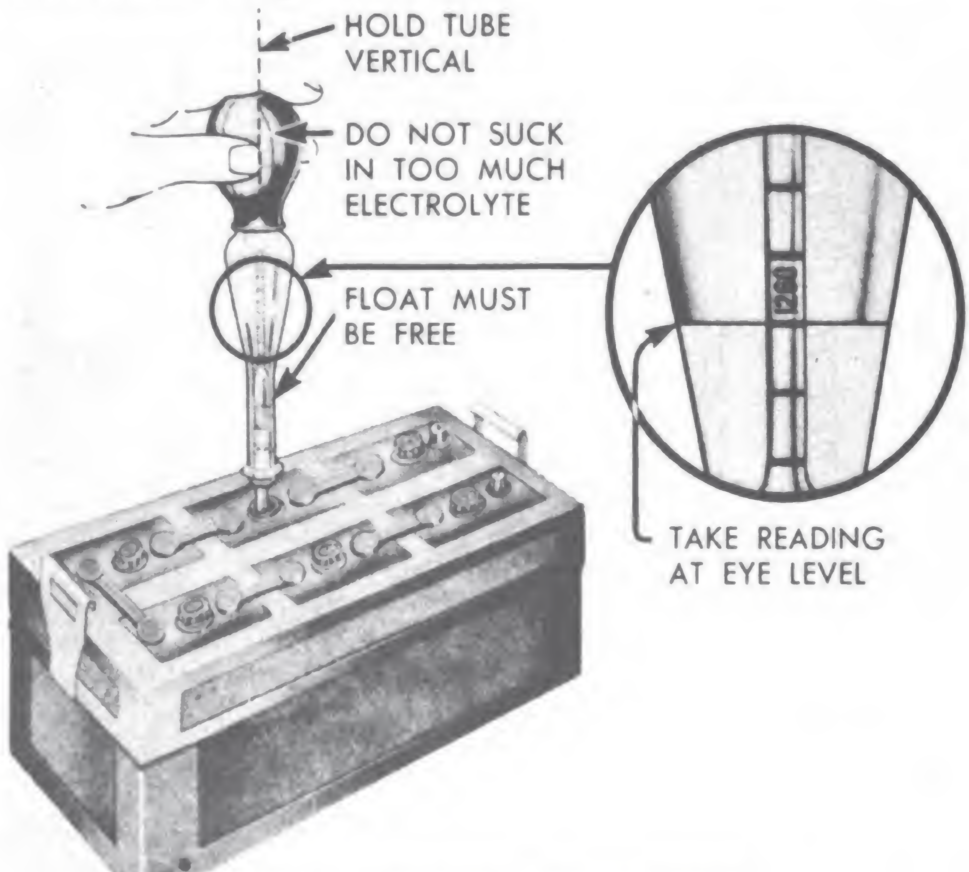


Figure 57.—Using the hydrometer syringe.

The rubber tube is inserted into the cell being tested. By squeezing the rubber bulb, and then releasing it, you can draw some of the electrolyte into the glass tube. The hydrometer

will float in the liquid. When you read the hydrometer, be sure to hold it up to eye level to get a true reading. Also be sure that the syringe is held straight up and down. This will prevent the hydrometer float from rubbing against the wall of the syringe. A clear picture of this can be seen in figure 57. Always return the electrolyte to the cell from which it was taken.

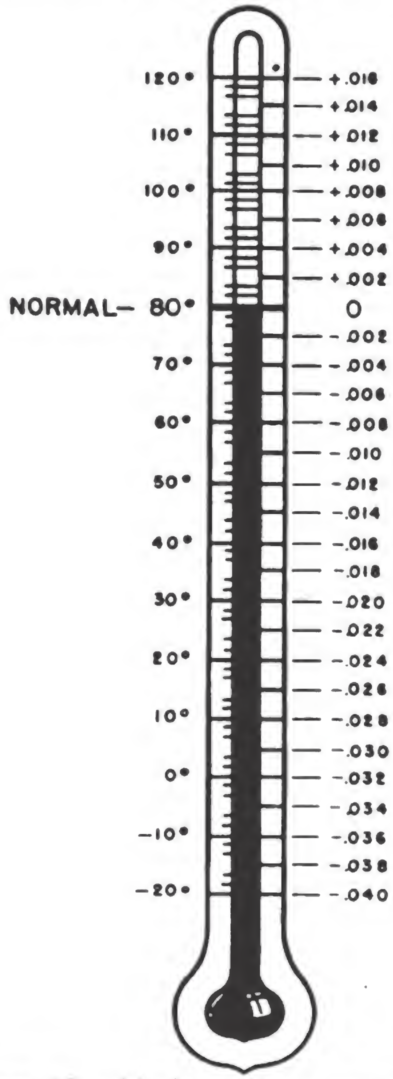


Figure 58.—Hydrometer correction chart.

Hydrometer Corrections

The specific gravity of an electrolyte is actually a measure of its density. The electrolyte becomes less dense as its temperature rises, and more dense as its temperature falls. Thus, a high temperature means a low specific gravity and a low tem-

perature a high specific gravity. The hydrometer that you use is calibrated to read specific gravity at only one temperature—80° F. Under normal conditions the temperature of your electrolyte won't vary much from this mark. However, large changes in temperature require a correction in your reading.

For EVERY 10-degree change in temperature ABOVE 80° F, you must ADD 0.004 to your specific gravity reading. For EVERY 10-degree change in temperature BELOW 80° F, you must SUBTRACT 0.004 from your specific gravity reading. Suppose you have just taken the gravity reading of a cell. The hydrometer reads 1.280. A thermometer stuck in the cell indicates an electrolyte temperature of 60° F. That's a difference of 20 degrees from the normal of 80° F. To get the true gravity reading you must subtract 0.008 from 1.280. Thus the specific gravity of the cell is actually 1.272. Figure 58 is a hydrometer correction chart. From it you can obtain the specific gravity correction for any temperature change above or below 80° F.

CHECKING THE STORAGE BATTERY

You've heard the saying, "An ounce of prevention is worth a pound of cure." It applies to the storage battery as well as other things. Keeping a check on storage battery condition means less hours of repair work. It also pays off in efficiency of operation.

Battery Terminals

The cables which carry the current to the equipment are fastened to the battery terminals by copper clamps. The acid fumes from the battery cells react with the copper to form a hard, greenish-white deposit. That spells trouble for you. Besides causing corrosion, it gets down between the terminal post and the cable clamp. Instead of a tight connection, you have a high resistance joint. The result is loss of power. Figure 59 shows you the appearance of corroded terminals.

You should inspect battery terminals at least once a week. If you find them covered with waste formation, you must remove it immediately. One pound of plain baking soda (the kind used in mess halls) mixed with one gallon of water will do

the trick. Remove the cable clamps from the terminal posts and wash both with the soda solution. Don't expect the deposit to disappear. The soda solution only softens it. You must then scrape it away with a knife or stiff brush. After you remove the deposit, wash all parts with plain water and reconnect the cables.

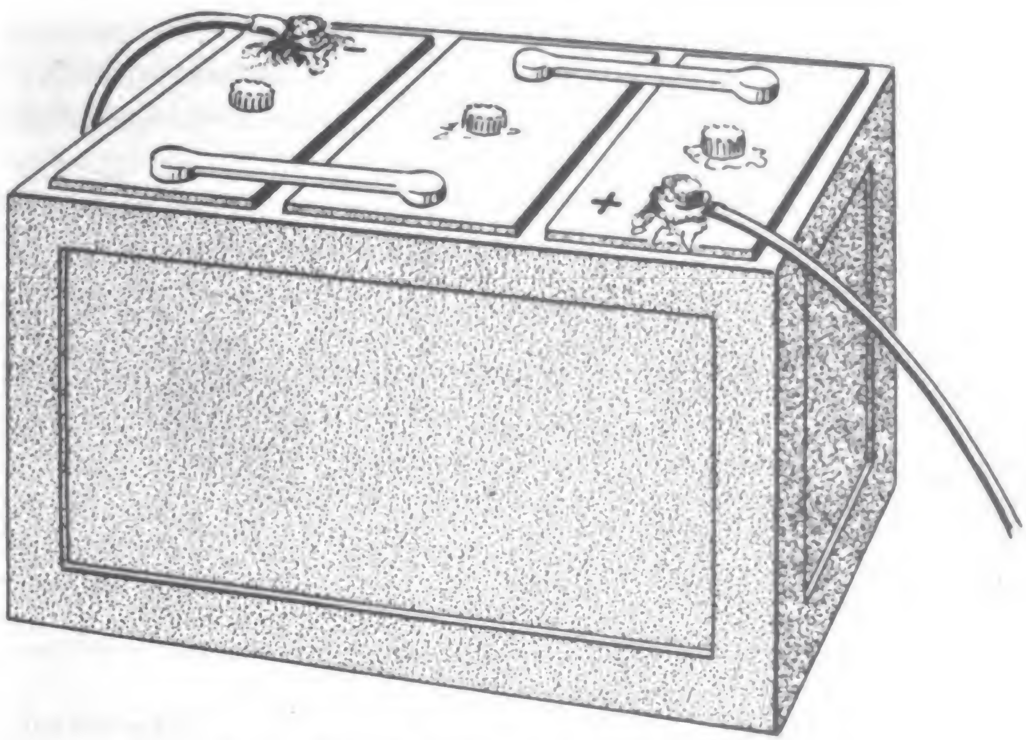


Figure 59.—Appearance of corroded terminals.

Remember that "ounce of prevention"? You can use it here. A little bit of ordinary vaseline applied to the battery terminals will prevent corrosion. If vaseline is unavailable, you can use a thin film of general-purpose grease. Don't leave the vaseline on for long. It collects dirt like flypaper collects flies. If you allow the dirt to build up, it will act as a leakage path for the current. At regular intervals you must clean the top of the battery of all dirt and vaseline. Just be sure to coat the terminals with new vaseline.

Electrolyte Level

Place a shallow pan of water outside on a hot day and things happen. The water doesn't boil, and yet it will eventually dis-

appear. Of course, you know it changes to vapor. The point is, you need only a temperature of 80° or 90° F. to do it.

The electrolyte contains water. It also operates in a temperature range of the high 80's. So you shouldn't be surprised to find that the water evaporates from it too. Unless you regularly replace that water, the plates will be exposed. A plate exposed to the air becomes dry and useless.

Your daily and weekly inspection should include a check of the electrolyte level in each cell. PURE WATER should be added

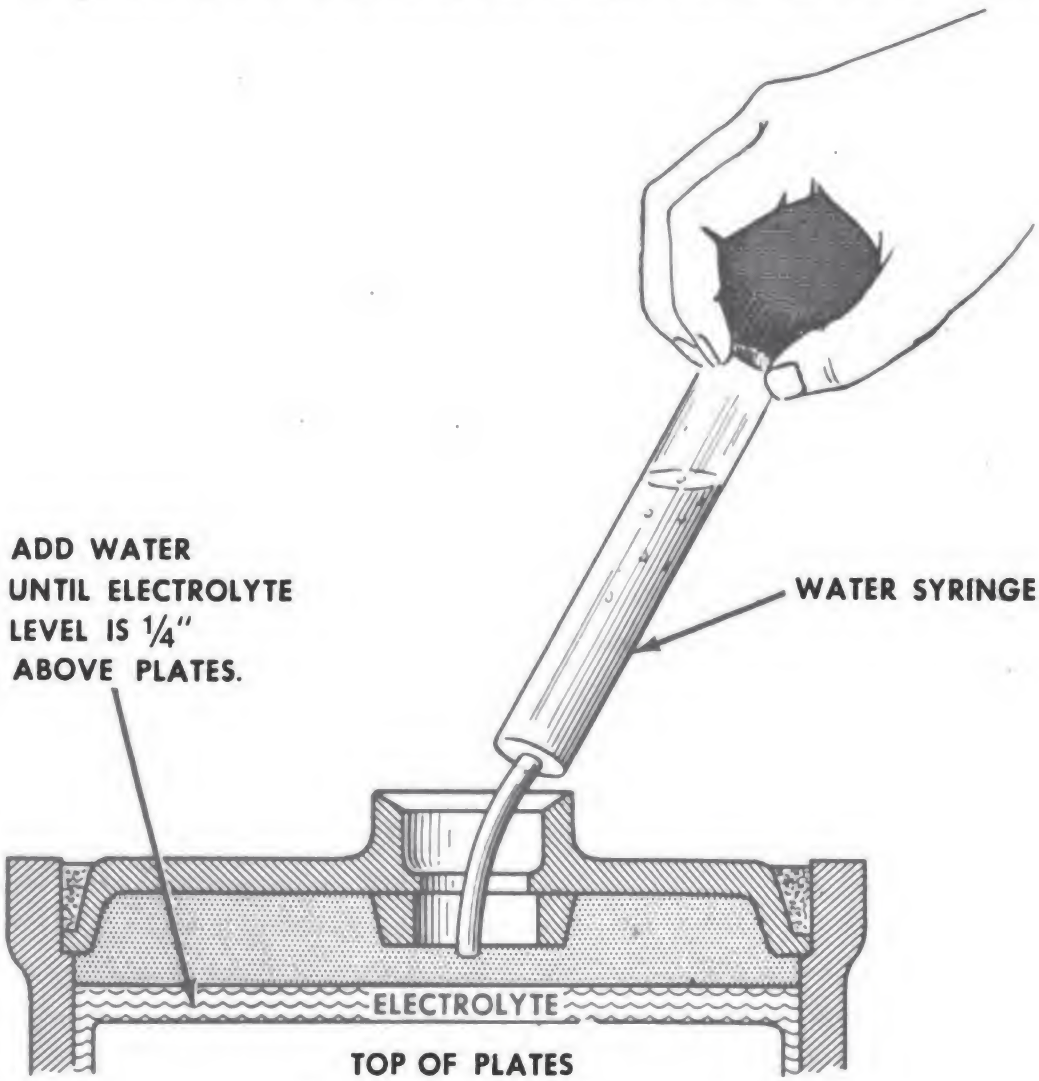


Figure 60.—Adding distilled water.

to any cell in which the electrolyte level is below the top of the plates. Add the water until the electrolyte level is at least

one-fourth of an inch above the plates. This is shown in figure 60. When you inspect the cell, take a look at the vent plug. The air vent in it should be clear at all times. If it is plugged up, run a short wire through it.

Battery Condition

A doctor determines a patient's condition by keeping a check on his temperature. You determine the battery's condition by keeping a check on its specific gravity. The doctor uses a thermometer. You use a hydrometer.

A battery used in normal climates will have a hydrometer reading of 1.250 or better on each of its cells when fully charged. If your hydrometer readings are less than 1.240, the battery

BATTERY LOG

Battery Rating: 6 volt, 100 ampere-hour

Date tested	Cell #1 Reading	Cell #2 Reading	Cell #3 Reading	
3 May	1256	1256	1255	
5 May	1252	1252	1251	
7 May	1250	1251	1249	
8 May	1250	1250	1200	
9 May	1250	1250	1125	
9 May	Battery removed for inspection			

Figure 61.—A battery log.

should be removed from the circuit and charged. NEVER ALLOW THE SPECIFIC GRAVITY TO DROP BELOW 1.225.

In tropical climates the specific gravity of a charged cell should be 1.225. This type of a battery should be recharged when its specific gravity drops below 1.135.

Not all of the cells of the battery will have the same gravity readings. You've got to expect a little variation in each one. If the specific gravity of one cell continually shows a wide difference from the others, however, the battery should be sent to the repair shop.

Never take a hydrometer test immediately after you add water to the cell. It won't give you a true reading. You must allow enough time for the water to completely mix with the original electrolyte.

A battery log is shown in figure 61. It will help you in maintenance inspection. It's nothing more than a record of specific

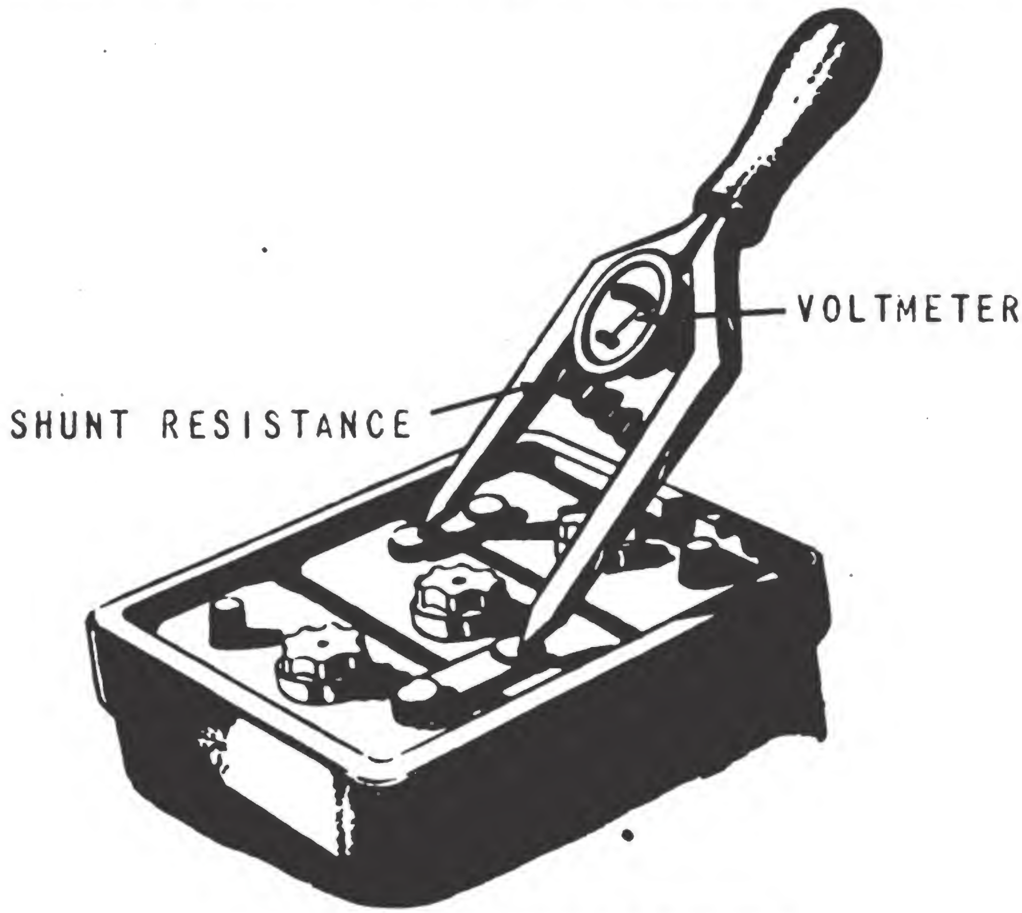


Figure 62.—High-amperage discharge tester.

gravity readings taken over a period of time. From it you can get the entire history of the battery. If a battery develops trouble, you can trace and locate the bad cell by the aid of the battery log.

Hydrometer readings don't always give a true picture of a battery's condition. It is sometimes necessary to take voltage readings too. The voltage of a fully charged cell should measure about 2 volts under NORMAL LOAD CONDITIONS. That means taking a voltage check while the battery is still in the circuit.

Suppose that after taking a hydrometer reading on each cell of a 6-volt battery, you find that all have a specific gravity above 1.250, yet the battery is barely producing enough voltage to run the equipment. You follow the hydrometer check with a voltage test of each cell. You discover that two of the cells have a normal 2-volt output, but the third cell is only producing 1.5 volts. Actually, then, your battery is bad, although your gravity readings indicated it as good. You can see why a hydrometer AND voltmeter test is the best check on a battery's condition.

You can test the battery when it is out of the circuit. But you must shunt (parallel) a resistance across the battery terminals. This resistance takes the place of the load. Some battery testing voltmeters (figure 62) are equipped with this shunt resistance. When you place the voltmeter across the battery terminals you also connect the resistance in at the same time. If the cell is good the voltage will stay above 1.75 volts. A voltage reading below 1.75 volts for any cell indicates a bad battery. This type of test draws considerable current from the battery cell. For this reason it is called a HIGH-AMPERAGE discharge test. Don't test any one cell for more than 15 seconds. If the current drain is continued beyond this time, you might ruin the battery.

CHARGING THE STORAGE BATTERY

When a battery discharges, the acid in the electrolyte combines with the material in the plates. It is this chemical action which gives you electrical energy. During this period a thin film of lead SULPHATE forms over the surfaces of the positive and negative plates. When the plates are completely covered with this sulphate, the battery action stops. You can see why. The sulphate acts as a barrier between the plates and electrolyte.

If the electrolyte can't reach the plates, the chemical action ceases. Your battery is DISCHARGED.

When you CHARGE a battery you remove the sulphate film from the plates. Then your battery is ready to produce electrical energy again. It's important that you recharge a battery before the sulphate film becomes hardened. Hard sulphate is impossible to remove. If the plates are covered with spots of hard sulphate, the capacity of the battery goes down. That's because there's a decrease in plate area.

When a battery discharges, electrons leave the negative terminal. They travel through the load and then return to the positive terminal. To charge a battery this action must be REVERSED. To force electrons into the battery THE CHARGING SOURCE MUST HAVE A VOLTAGE GREATER THAN THAT OF THE BATTERY. The electrons must be FORCED into the negative terminal. The electrons come from a DIRECT CURRENT charging source.

Constant Current

Figure 63 shows the hook-up for charging storage batteries by the CONSTANT CURRENT method. Following the electron

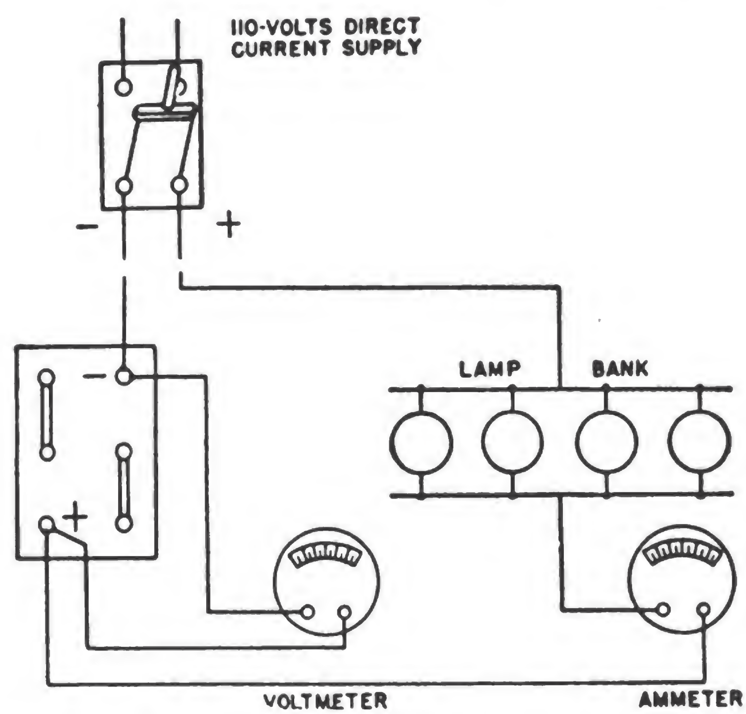


Figure 63.—Constant-current charging circuit using a lamp bank.

flow will help you understand the circuit. The electrons leave the NEGATIVE side of the switch and travel over to the NEGATIVE terminal of the battery. Then they go through the battery (charging takes place) and emerge at the positive terminal. From the positive terminal they move through an ammeter where their rate of flow (amperage) is recorded. Finally, they pass through a lamp bank and end up at the positive side of the current supply Notice that this is a SERIES circuit.

You might be wondering what part the lamp bank plays in the circuit. It's put there to limit the amount of current passing through the battery. If the 110-volt supply was placed directly across the battery, a large current would flow. High-charging current means excessive heat and short battery life.

The lamps are rated at 110 volts, 100 watts. Each will limit the current to one ampere. Five of them in parallel will limit the current to five amperes. Thus, the battery in figure 63 is being charged with five amperes.

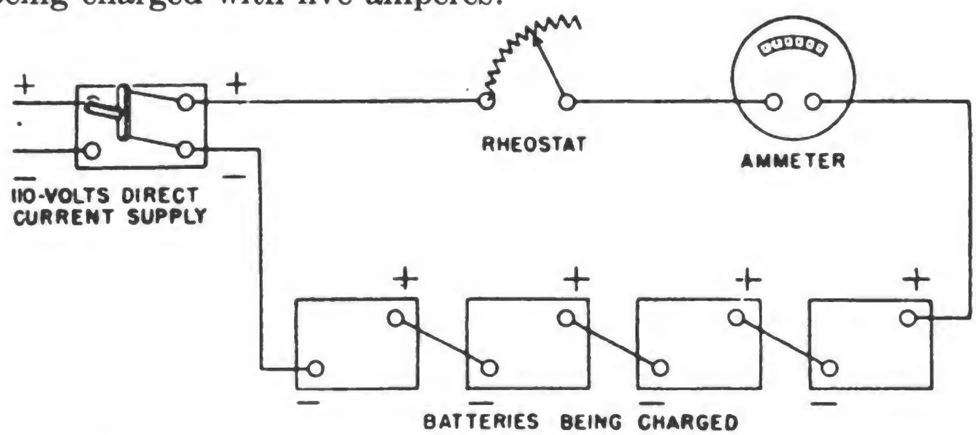


Figure 64.—Constant-current charging circuit using a rheostat.

Since the lamps are being used to absorb power, you could replace them with a variable resistor. The variable resistor is known as a rheostat. IT ALLOWS YOU TO CONTROL THE AMOUNT OF CURRENT FLOWING IN THE CIRCUIT. It is also possible to place more than one battery in a constant-current system. Just be sure that they are in SERIES with each other, and that their total voltage is LESS than the supply voltage. Don't mix 6-volt and 12-volt batteries together. A circuit using a variable resistor is shown in figure 64.

The constant-current charging method has one disadvantage. THE CHARGING CURRENT REMAINS AT A STEADY VALUE UNLESS YOU CHANGE IT. A battery at the beginning of a charge requires a reasonably high current. As the battery regains its strength, however, less current is needed. If you allow the current to STAY at a high value, the battery will overheat. That means destroyed plates and a trip to the repair shop.

The amount of charging current that you start and finish with is not the same for all batteries. It depends on how old the battery is, its condition, and state of discharge. Actually, you can start with any value of charging current that you wish—so long as the ELECTROLYTE TEMPERATURE DOES NOT EXCEED 110° F.

Another way of determining whether you have too much current is to check the appearance of the electrolyte. Excessive current will cause violent bubbling and gassing. When this

Figure 65.—Full-wave bulb rectifier.

happens reduce your current until the reaction stops. By keeping a constant watch on electrolyte temperature and appear-

ance, you can control the current during the entire charging period.

If you have an ALTERNATING current supply, it must be changed to DIRECT current when charging the battery. A RECTIFIER is used for this purpose. The rectifier may be either a BULB rectifier or a DISK rectifier. Both do the same job—they permit the current to flow in one direction only. The tungar bulb is more efficient, but the disk rectifier is more rugged.

A common type of bulb-rectifier charger is shown in figure 65. It is a FULL-WAVE rectifier and thus contains TWO bulb-rectifier tubes. The bulb rectifiers are mounted inside the cabinet along with the other parts of the charging circuit. An ammeter and plug-in controls are mounted on the panel face. Notice the wires which extend from the bottom of the cabinet. The wires marked *A* and *B* connect to the 115-volt a.c. supply. The wires marked *C*, *D*, and *E* carry the charging current to and from the batteries.

Since this is a full-wave battery charger it takes the place of two half-wave chargers. Notice the two identical ammeters and plug-in controls. Each controls half of the full-wave charging circuit. Batteries connected between wires *C* and *D* are controlled by the plug-in controls and ammeter on the left side of the panel. Batteries connected between wires *E* and *D* are controlled from the right side of the panel. An "on-off" switch, mounted in the middle of the panel, controls the a.c. input.

You can connect as many as twelve 6-volt batteries in each line. Of course, they must be in SERIES with each other. Figure 66 shows you five 6-volt batteries connected in the left-hand side of the circuit, and five 6-volt batteries connected in the right-hand side. The amount of charging current is determined by the plug-in controls. They take the place of the rheostat in the charging circuit of figure 64. Notice the numbers which are marked opposite each hole. They correspond to the number of batteries being charged. In figure 66 you would set the plug into the hole marked "5" on the left-hand side, and into the hole marked "5" on the right-hand side.

The three horizontal plug-in holes at the bottom of each half of the panel are used as a fine control of the charging current.

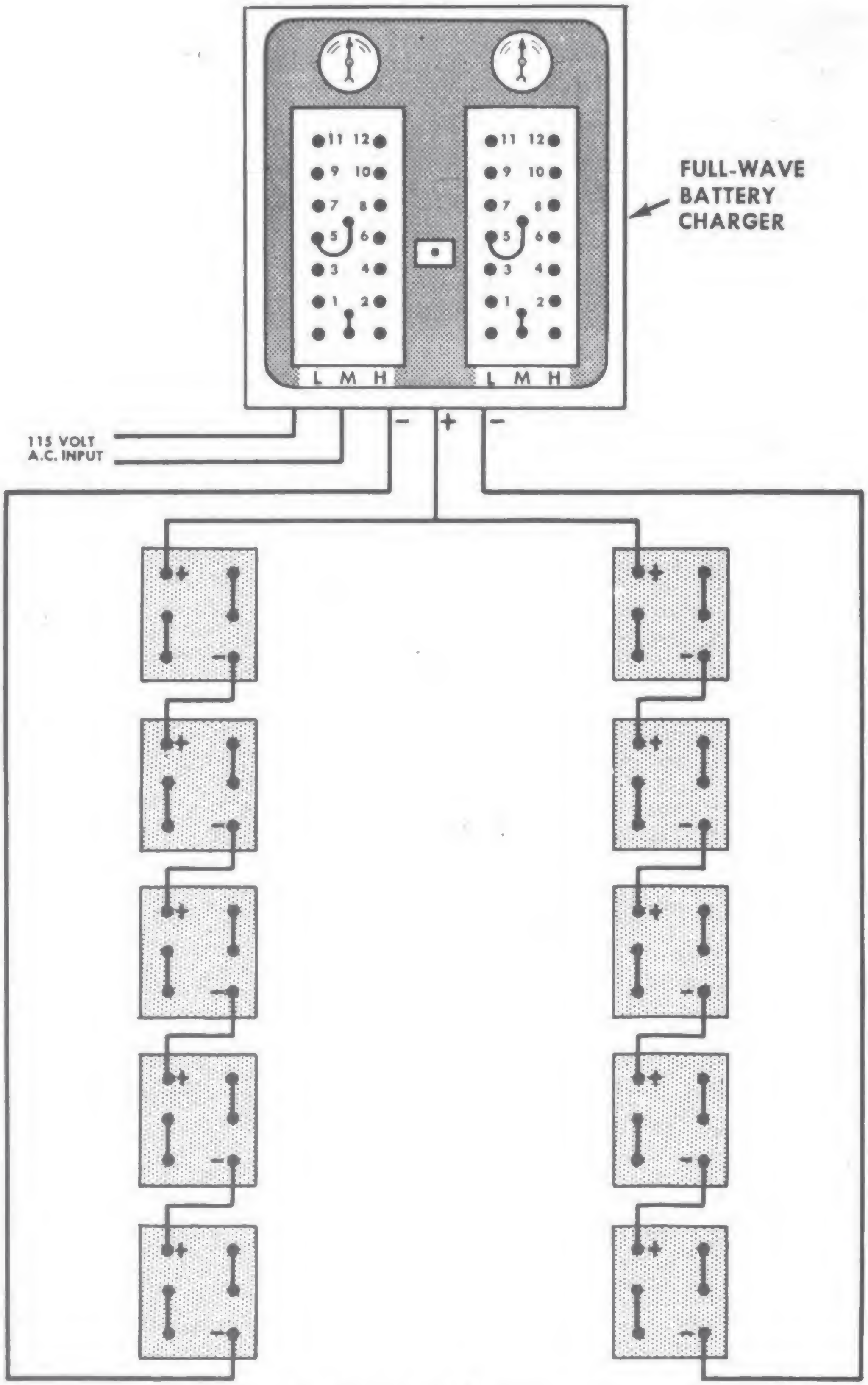


Figure 66.—Using the full-wave charger.

They are marked LOW, MEDIUM, and HIGH. The one you plug into depends upon how fast you want the batteries to be charged. Keep an eye on the ammeters. When they indicate that the charging current is too high, reduce it by changing the position of your fine control.

Constant Voltage

In the constant-current method of charging, you had to reduce the current as the battery regained its strength. In the CONSTANT-VOLTAGE method the current is reduced or tapered off AUTOMATICALLY. The d.c. charging voltage is kept at a

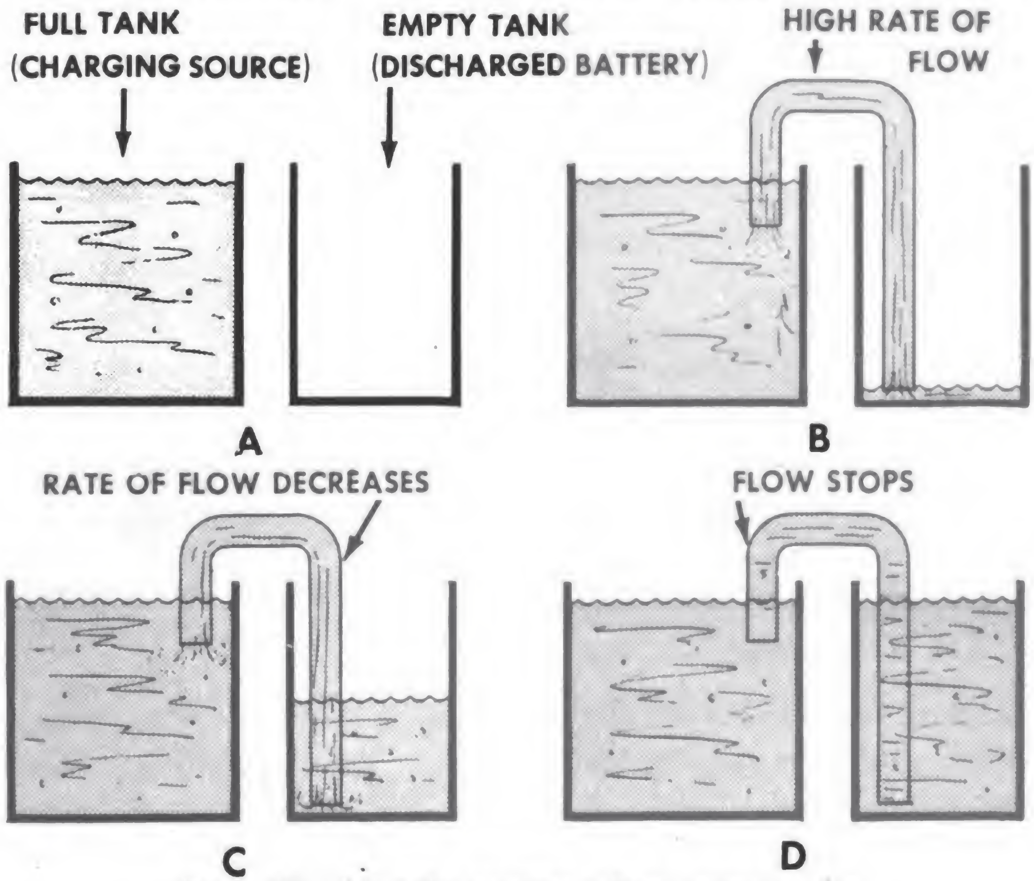


Figure 67.—How the constant-voltage system works.

constant value. Its value is very close to that of the battery when it is fully charged. For example, if you were charging a 6-volt battery, you would use a charging voltage of about 7.5 volts. A 12-volt battery requires a charging voltage of 15 volts.

Understanding how the constant-voltage system works is easy—if you look at figure 67. View *A* shows two water tanks.

One tank is full. It represents the charging source. The other tank is empty. It represents the discharged battery. The full tank has been designed so that the level of water always remains the same, no matter how much is withdrawn. In view *B* a pipe connects the full tank to the empty tank, in the same way the wires connect a battery to the charger. Water flows by siphon action from the full tank to the empty tank at a rapid rate. This corresponds to the high rate of current flow when the battery is first placed on charge. The reason, of course, is the LARGE DIFFERENCE in potential which exists between the discharged battery and the charging source.

In view *C* the tank is half full. This represents the battery which has received one-half of its charge. The flow of water into the tank AUTOMATICALLY decreases, since the difference in

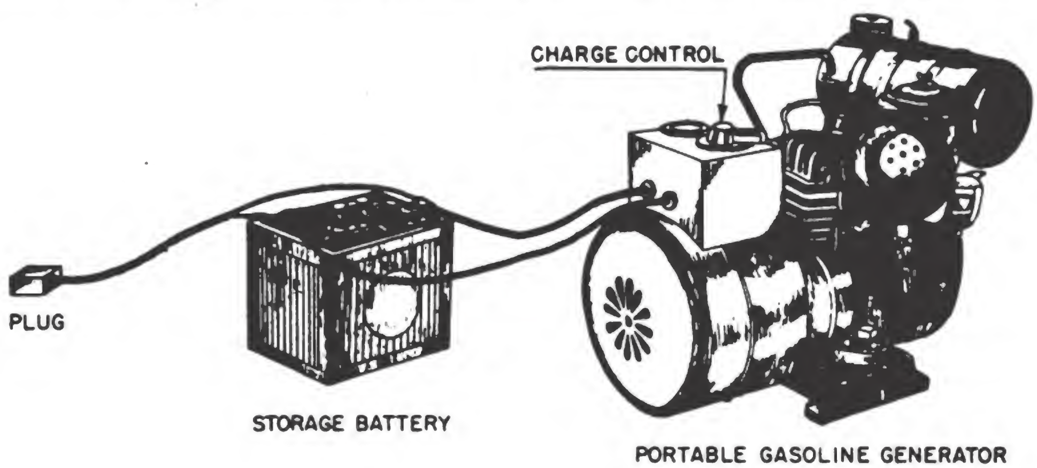


Figure 68.—Gas-driven portable charger.

pressure has become smaller. The same applies to the current flowing into the half-charged battery. View *D* shows you the two tanks filled to the same level. No water flows between them because they are both at the same pressure. Similarly, when the battery reaches full charge, its voltage is close to that of the charging source. Therefore, it receives very little, if any, current from the charger. Using the constant-voltage charger means less danger from excessive current. THE CURRENT WILL TAPER OFF AUTOMATICALLY.

The source that you obtain your charging current from is called a motor generator set. The motor and generator are

mounted on the same shaft. As the motor turns, it drives the generator at equal speed. The generator produces either 7.5 volts or 15 volts, depending on the type used. Figure 68 shows a portable charger. The motor is driven by a one-cylinder gas engine. The generator output is 7.5 volts. Notice how the battery is connected to the charging circuit.

In more permanent installations, the motor generator is operated by 115 volts a.c. The output from the generator, using a three-wire system, is actually 15 volts. This enables you to charge both 6- and 12-volt batteries at the same time. Figure 69 will help you understand this set-up. The three leads from the generator are attached to large diameter wires mounted on a charging panel. To charge a 12-volt battery you simply connect it to the two outside wires. To charge a 6-volt battery you connect it to ONE of the outside wires and to the middle wire. Notice that the batteries are placed in PARALLEL. That's a feature of the constant-voltage method of charging.

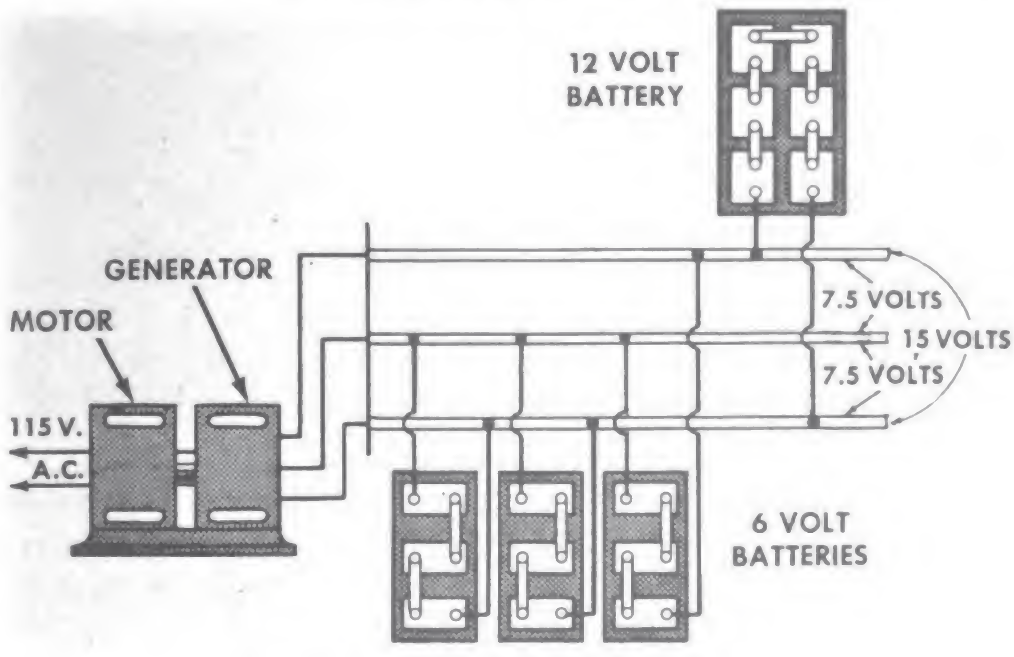


Figure 69.—Three-wire charging system.

GOOD CHARGING PRACTICE

It's a simple matter to connect the battery to the charger. And it doesn't take much effort to turn the switch on. What

counts, however, is the precautions you take BEFORE and DURING the charging period. Good charging practice involves the following measures:

1. Connect positive terminal of battery to positive terminal of charger. Do the same with negative terminals. Terminals are distinguished by plus and minus markings, a slightly larger positive pole, or red paint on top of the positive pole.

2. Be sure that the vent holes are unplugged. DO NOT REMOVE THE VENT PLUGS DURING CHARGING if the battery has a liquid level control. However, if there is no level-control device, the plugs should be removed. Be sure to replace vent plugs when the battery is removed from the charging rack.

3. Check electrolyte level before charging begins and at frequent intervals during charging. Add distilled water if level of electrolyte is below the top of the plates.

4. Keep charging room well ventilated. DO NOT SMOKE NEAR BATTERIES BEING CHARGED. Batteries on charge release hydrogen gas. A small spark might cause an explosion.

5. Take frequent hydrometer readings and record them. The specific gravity of the cells should rise during charge. If any cell's specific gravity does not rise during charge, remove the battery for repair.

6. Keep a constant watch for excessive gassing. This is especially important when using the constant-current method of charging. It must also be watched at the very beginning of the charge when using the constant-voltage method. Reduce the charging current if gassing takes place.

7. Do not remove a battery until it has been completely charged. A battery is fully charged when THREE SUCCESSIVE HALF-HOUR HYDROMETER READINGS SHOW A CONSTANT VALUE.

REPAIRING THE STORAGE BATTERY

The life of a battery depends on the care it receives. Carelessness and neglect cause batteries to fail. A battery becomes repair shop material when the following happen:

1. The electrolyte freezes. A discharged battery becomes a

perfect set-up for freezing in cold temperatures. When a battery is discharged, its electrolyte contains a large amount of water. Some of this water is in the positive plates. When it freezes, the expansion causes the active material to break loose. If too much material is lost, the plates won't function normally.

2. The plates become sulphated. Sulphation is normal action when a battery discharges. But if it isn't removed by immediate recharging, the sulphate becomes hard. Badly sulphated plates cause a reduction in battery capacity. The plates will eventually buckle.

3. The separators become damaged. A separator exposed to air will rot away, permitting contact between negative and

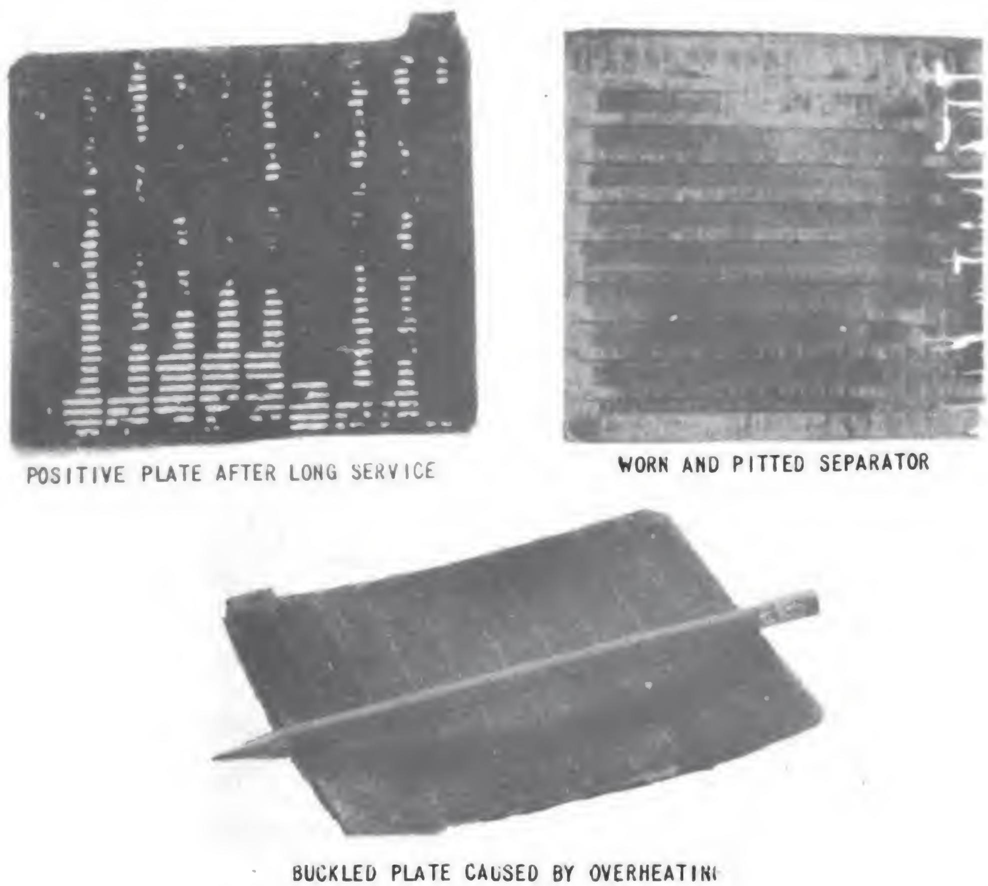


Figure 70.—Worn plates and separators.

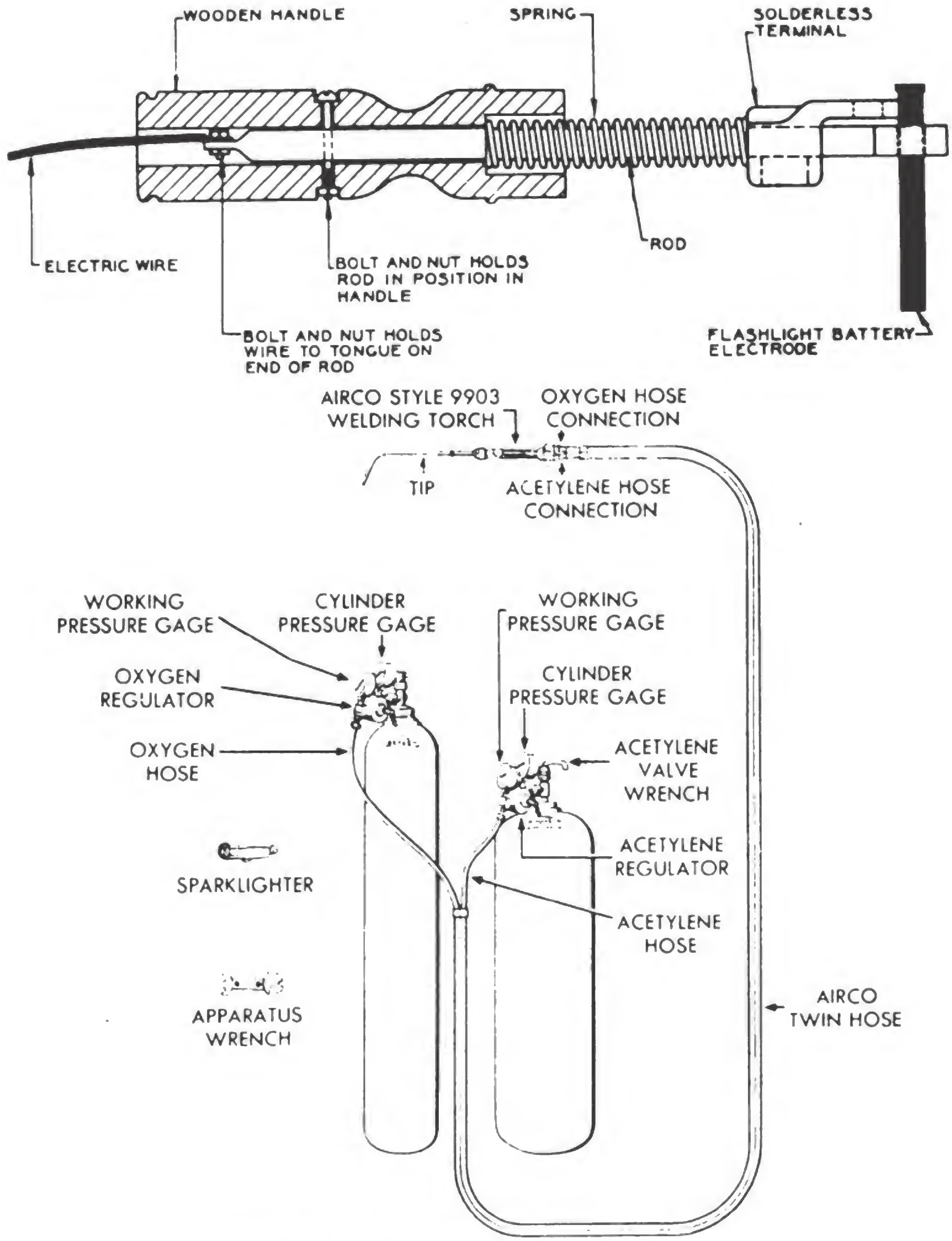


Figure 71.—Two types of lead-burning tools.

positive plates. A plate might also become clogged with dirt. As a result, the battery acts sluggish and has a reduced capacity.

Figure 70 shows you the effect of freezing and sulphation on the plates of a battery. It also shows you the appearance of worn and pitted separators.

When you receive the battery, it is completely sealed. You must take it apart for repairing and then put it together again. Dismantling and reassembling plates, groups, plate straps, cell covers, and cell connectors require HEAT. You obtain this heat from an OXYACETYLENE TORCH or a CARBON-BURNING TOOL. Figure 71 shows you what these two types of equipment look like.

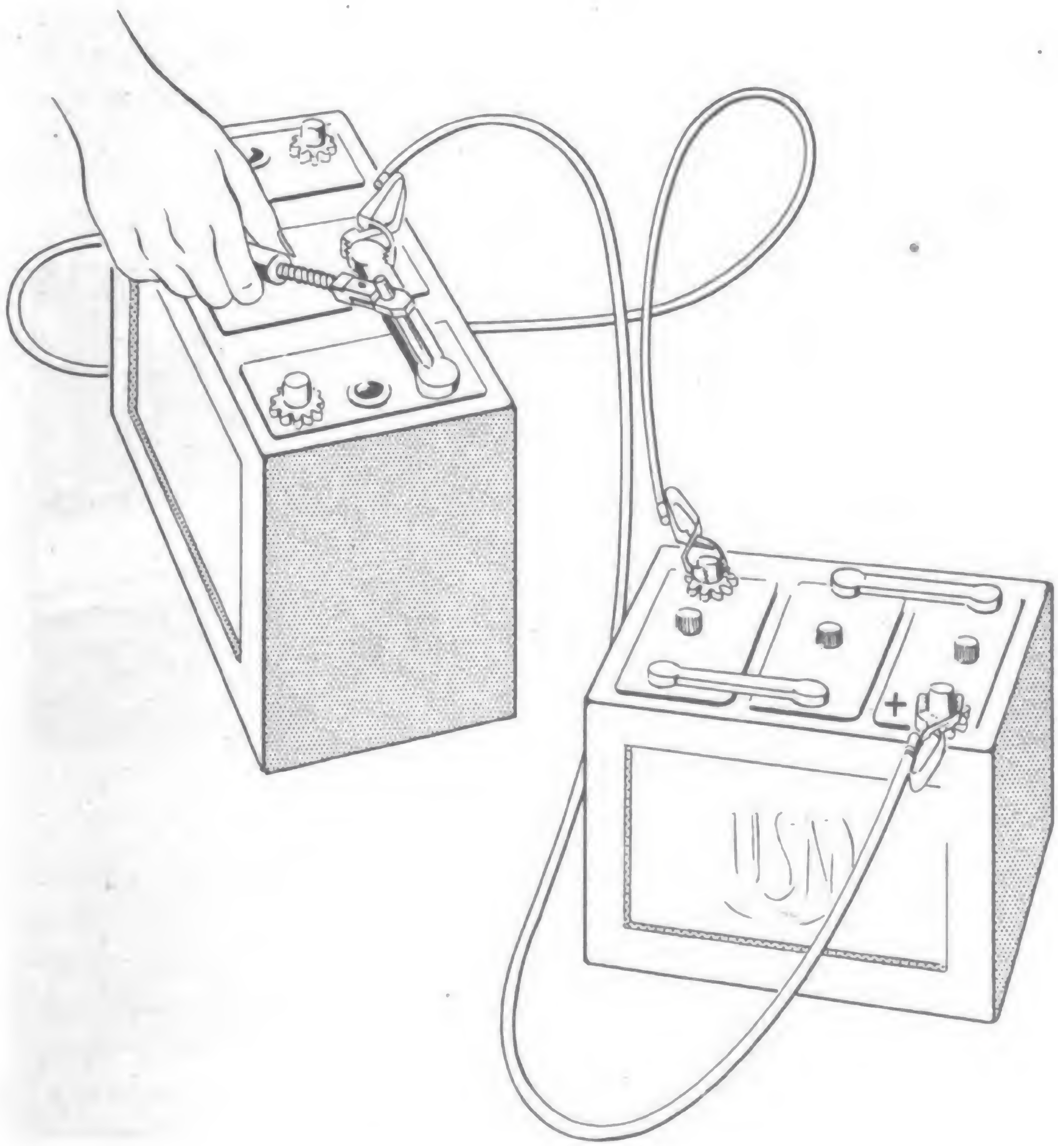


Figure 72.—Carbon-burning tool operation.

Using the oxyacetylene torch requires a lot of know-how. You can get some of that know-how by reading *Use of Tools,* NavPers 10623. But your best bet is to ask someone who is familiar with the equipment to show you how to use it. When you feel that you can handle the torch, try some practice runs on old discarded lead battery parts. Learning how to fuse them together sets you up for the real job when you repair batteries. Fusing lead parts together is called LEAD BURNING.

The carbon-burning tool is simple and easy to use. You get your power from a spare 6- or 12-volt battery. Figure 72 shows you how the carbon-burning tool works. The carbon rod is connected to a terminal of the spare battery. The other ter-

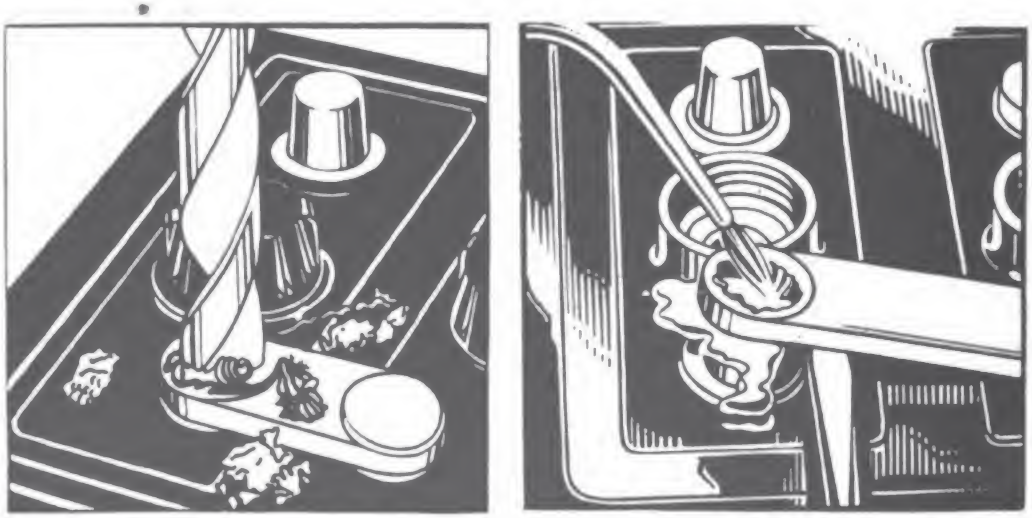


Figure 73.—Removing cell connectors.

minal of the battery is connected to the lead parts being fused together. When the carbon rod is touched to the lead parts you have a complete circuit. The current flows from the negative terminal of the battery through the lead parts, then through the carbon rod and back to the positive terminal. Since there is very little resistance in the circuit the current flow is heavy. This heavy current through the carbon rod causes it to reach a red heat. It is this heat which melts the lead parts together. Any extra lead needed is obtained from a lead filler rod.

Dismantling the Battery

When you open a cell of the battery, you must first remove the cell connectors which are attached to the cell terminals. One method of removing the connectors is shown in figure 73. Here you simply use an ordinary carpenter's brace to drill out the weld. A standard $\frac{5}{8}$-inch twist drill bit will do the trick, although a hollow bit helps to save the terminal post. Drill down about one-fourth of an inch. You then break the connection either by prying the connector off with a screw driver, or by twisting it off with pliers. Make sure that you brush the lead borings from the top of the battery.

Figure 73 shows you still another method of removing cell connectors. A torch or carbon-burning tool may be used. The tool is applied to the terminal in a circular motion. When a molten pool forms, use a screw driver to break the connection between terminal post and connector. Bend the connector back out of the way.

Figure 74.—Removing sealing compound.

Now you're ready to unseal the cell cover. That means removing the battery sealing compound between the cell cover

and the battery case. You can soften the compound with a hot putty knife. After the compound has been loosened, it's a simple matter to scrape it out with the putty knife. You can see the operation in progress in figure 74.

Since you will be using an open flame near the battery you must be sure that no gases are present. To eliminate the possibility of gases in the cell, remove the vent plug and blow into the cell with the help of a rubber hose. This will force the gases out. It is also a good idea to remove as much of the electrolyte as possible. A small rubber hose inserted in the cell can be used to siphon out the electrolyte down to the top of the plates. These precautions must be taken, of course, before you remove the battery sealing compound.

Your next step is to lift the element and attached cell cover out of the cell. Using two pairs of pliers to grasp the cell terminals, ease the unit out, and then rest it on the edge of the battery container. This allows the electrolyte to drain away. Figure 75 shows you the element in this position.

Figure 75.—Draining the element.

Now you are ready to remove the separators. First, place the element on its side and slightly spread the plates apart. Then PUSH each separator out toward the bottom of the element. Be careful not to damage the plates. Inspect the separators and discard those that are worn or pitted. Don't allow the separators to dry out. If you are not going to replace them immediately, store them in a jar of distilled water.

The positive and negative groups are held together by the cell cover. If you separate the groups, you must first remove the cell cover. You'll find three methods used to attach the cell cover to the terminal posts. They are shown in figure 76. The simplest is the SCREW-POST. A seal nut is the clamping device. It is screwed on the threaded terminal post. A post gasket maintains an airtight seal. To remove the cell cover you simply unscrew the seal nut.

The second method is the PUSH-ON type of construction. A grip is maintained between post and cover by a tight-fitting rubber bushing. You can always spot this type of construction

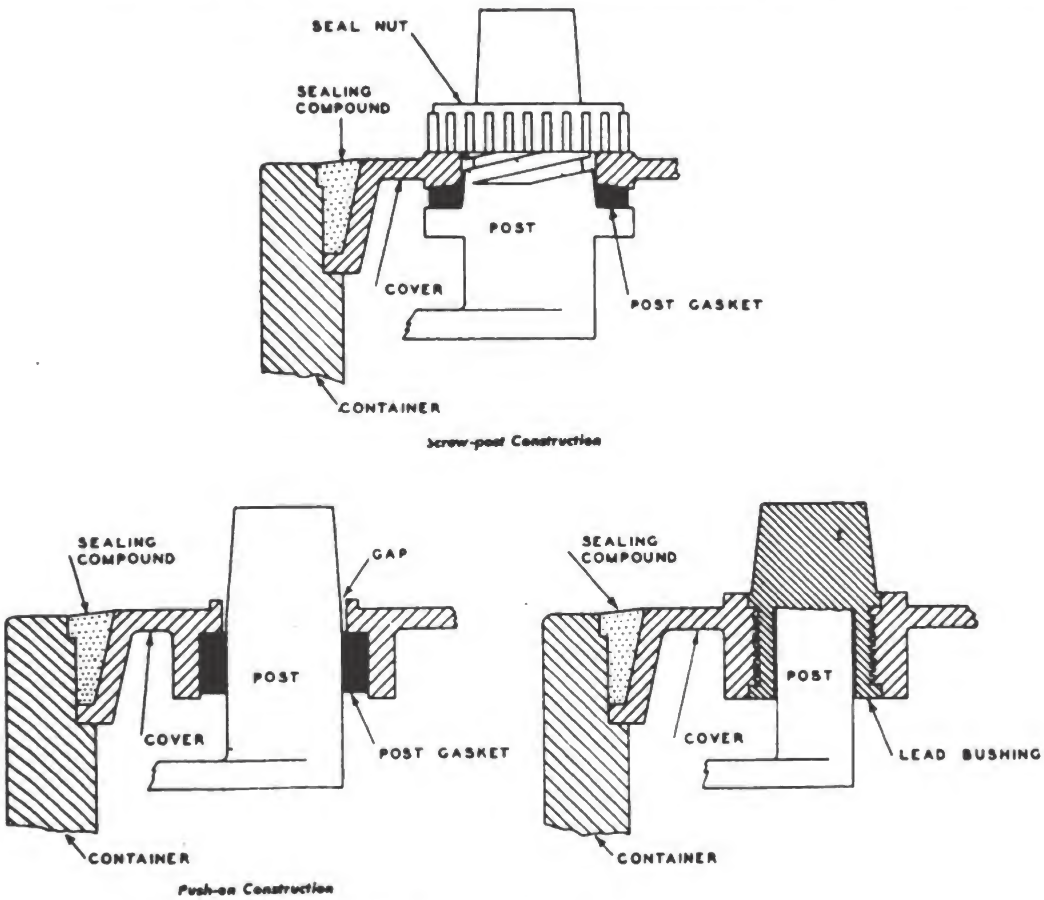


Figure 76.—Types of terminal construction.

by the circular space between the post and cover. You remove the cover by prying it off.

The LEAD BUSHING is the third type of attachment. The bushing is molded into the cell cover. The terminal post is

fused to the bushing. The only way you can remove the cell cover is by sawing through the terminal post. Use a small hacksaw blade for this job. Figure 77 shows you how it's done.

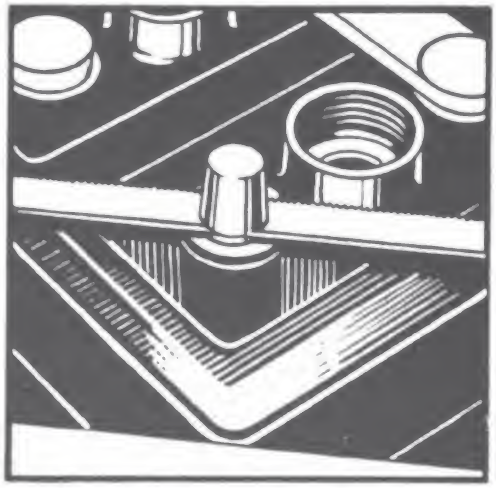


Figure 77.—Sawing through the terminal post.

Notice that the post is sawed off flush with the cell cover to break the weld connection. The cover is then slid off.

After the cell cover has been removed you are ready to separate the positive and negative groups. Simply grasp each terminal post and exert an outward and downward pull. When you have the plates apart, examine them carefully. Check for sulphated spots and loss of active material. If a group is bad, replace it with a similar-sized group. Your replacements are obtained from old batteries. That's a tip for you. Never discard a battery without first removing any negative or positive group which can be used later.

Never allow a negative group to dry out. Always keep it in a suitable container filled with distilled water until you are ready to use it.

Reassembling the Battery

After completing your inspection and replacement of parts, you are ready to put the cell together. Your first step is to interlace the negative and positive groups. Do this slowly to prevent damage to the individual plates.

Your next step is to attach the cell cover to the element. If you're working with a screw-post terminal, put the rubber

gaskets on the posts first. Then place the cell cover over the posts and tighten it down with the seal nut.

If you're working with the push-on type, a different procedure must be followed. First, place the rubber bushings in their sockets on the underside of the cell cover. To insure a tight fit, put a small amount of rubber cement or soft soap in the bushing hole. Then place the cell cover over the element so that it fits snugly on the terminal posts.

The lead-bushing type of construction requires still another method of attaching the cell cover. The bushings are already molded into the cell cover. All you have to do is place the cover over the element and weld each lead bushing to its corresponding terminal. If the terminal is too short to be welded to the lead bushing, it must be built up. A POST BUILDER is used. The post builder is simply a steel mold. Place the post builder in position as shown in figure 78. Use a lead-burning tool to

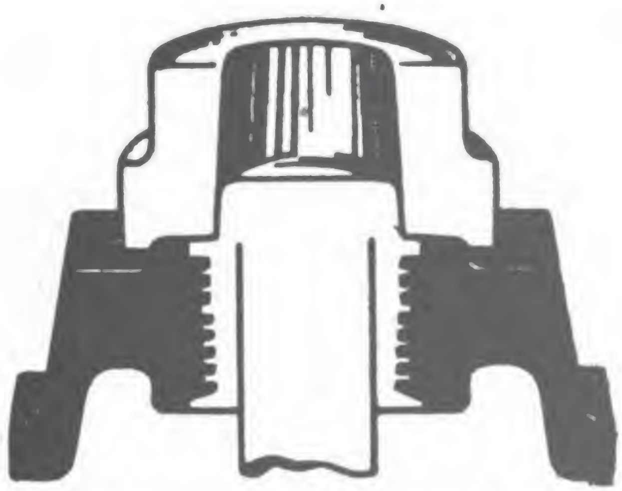


Figure 78.—Post builder in position.

melt the top of the post. Then apply additional lead from a lead stick just like you apply solder to a joint. Build the post up about three-sixteenths of an inch above the cell cover. After the lead has solidified you remove the post builder.

Now that you have the groups attached to the cell cover, you are ready to insert the separators. Place the group on its side. Slide the separators in between the plates as shown in figure 79.

When you put the separators in, be sure to place the grooved side against the positive plate. Also, make certain that the grooved channels will be in a vertical position when the element is standing upright.

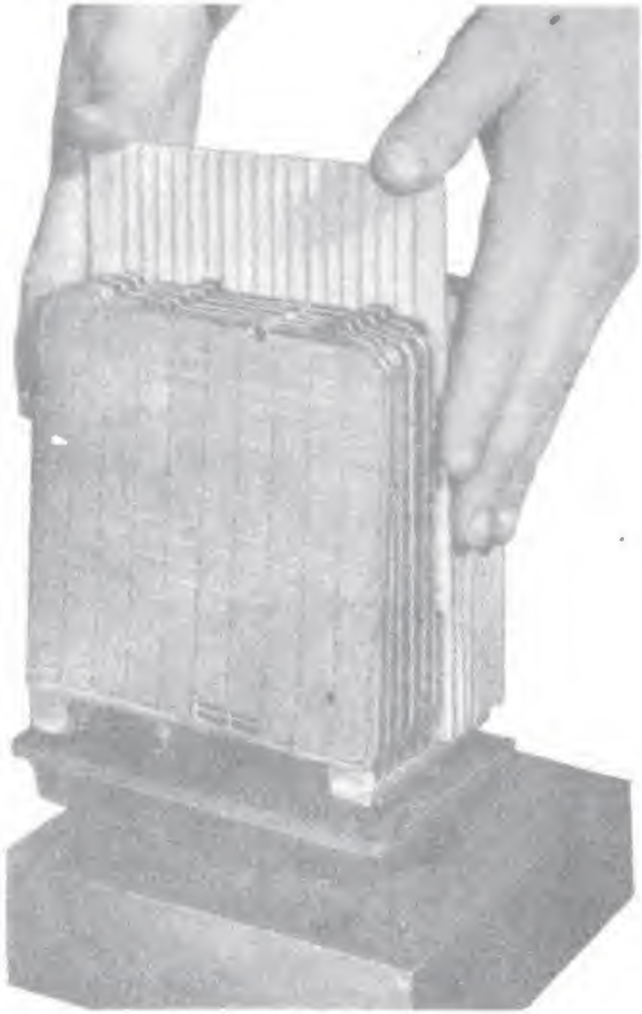


Figure 79.—Inserting separators.

Before you place the element into the cell compartment, do a little checking. Inspect the bottom of the cell. If you find a large amount of sediment in the sediment chamber, clean it out. Also check the battery case to see that it has no cracks. Now place the element into the cell. Make sure that you have the terminal posts in the correct position with respect to the other cells.

You're all set to join the cell connector to the terminal post.

First, bend the connector back to its original position over the post. Weld the connector to the post with a lead-burning tool or torch. Here's one operation in which you must use care. The connector is thinner than the post. If you hold the heat on the connector, it will melt before the post. You must apply the flame or lead-burning tool to the center of the post. When you see the post start to melt, move the torch in a circular

Figure 80.—Lead-burning the connector to the post.

motion to the outside. This brings the heat to the connector. Continue to apply the heat evenly to the connector until it melts and fuses with the post. You might find it necessary to add more lead by the use of a lead stick. Figure 80 shows you how this operation is performed.

The cell is now ready to be sealed. Before you pour the sealing compound, clean the cell cover and cell. The sealing compound will not stick to a wet and dirty surface. When you melt the compound, apply just enough heat to make it flow freely. Use an old coffee pot or metal can as a container.

Use a blow torch to preheat the edges of the cover and cell. Then pour the sirupy sealing compound into the groove. Let the compound dry. You will probably find that the compound will tend to shrink. If it does, use more compound to fill the spaces to the top of the cell cover. You finish the job by

scraping off the excess compound. Figure 81 shows the battery sealing compound being added to seal the cell.

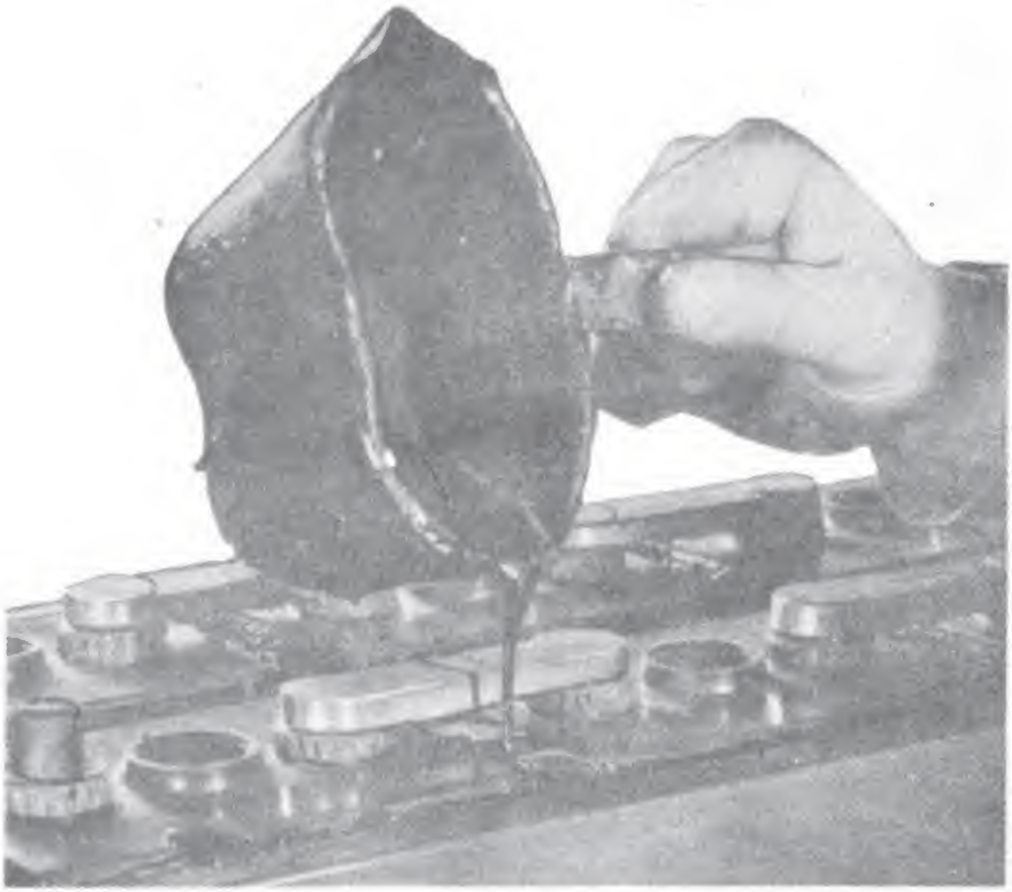


Figure 81.—Adding the sealing compound.

Adding electrolyte and charging the battery are the last steps in its assembly. If you have replaced the old groups with new ones, you must add full strength electrolyte (1.280 to 1.300). If you've found that it wasn't necessary to replace the old groups, a weaker electrolyte should be used. The old groups will already contain some sulphate from the battery's previous service. When the battery is charged, the sulphate will return to the electrolyte in the form of sulfuric acid. This will bring the weak electrolyte up to its full strength.

SUMMARY

A cell, or battery, converts chemical energy into electrical energy.

A primary cell is not renewable. A secondary cell can be recharged and used again.

The capacity of a cell is its ability to deliver current for a certain length of time. Capacity is rated in ampere-hours.

The total voltage of batteries connected in SERIES is the sum of their individual voltages. The total ampere-hour capacity of batteries connected in PARALLEL is the sum of their individual ampere-hour rating.

When preparing electrolyte, always add the acid to the water. Use distilled water when available. Rain water may be substituted in an emergency.

Maintenance of the storage battery includes frequent checks on battery connections and periodic hydrometer and voltage tests.

A fully charged battery in normal climates should have an electrolyte strength of 1.280 to 1.300. A fully charged battery in tropical climates should have an electrolyte strength of 1.200 to 1.225.

A battery must be charged with direct current. The voltage of the charging source must be greater than that of the battery, if charging is to take place.

In the constant-current charging method the batteries are connected in SERIES with the charging source. In the constant-voltage method the batteries are connected in PARALLEL with the charging source.

The electrolyte temperature of a battery being charged should not exceed 110° F. At the beginning of a charge, excessive gassing indicates that the charging current is too high.

Battery failures are the result of loss of active material from the plates, rotting of the separators, and freezing of the electrolyte.

QUIZ

1. What is a cell?
2. What is a battery?
3. What determines the e.m.f. produced by a cell?
4. What are the main advantages of the primary or dry cell?
5. What is the main advantage of the secondary cell or storage battery?
6. What are the three elements used in the common dry cell?
7. What are the three elements used in the common storage battery?
8. How are cells wired to secure a greater voltage?
9. How are cells wired to secure a greater current?
10. Name the two different voltages which are found in a cell or battery.
11. Which of the voltages is used in checking to determine if the battery is good?
12. You have a battery which will furnish 10 amps for 10 hours. How many hours will the same battery supply 5 amps of current?
13. What does specific gravity mean?
14. What is the specific gravity of pure water?
15. What should the specific gravity (in normal climate) of the electrolyte in a fully charged storage battery be?
16. Why must you be careful when handling sulphuric acid?
17. Explain the purpose of a hydrometer.
18. What is applied to the battery terminals to prevent the accumulation of the greenish-white waste deposit?
19. How is the terminal waste deposit softened so that it may be brushed off?
20. What should the reading of the hydrometer be for a fully charged storage battery in a tropical climate?
21. What is the minimum voltage which each cell should produce to indicate that the storage battery does not need recharging or repairs?
22. When first placing a storage battery on charge, what does excessive gassing indicate?
23. How do you determine when the storage battery should be removed from the charger?
24. Name two different methods of charging which are utilized in the various types of battery chargers.
25. When repairing the storage battery, what is done with the good separators if they are not replaced immediately?

CHAPTER 4

DIRECT CURRENT MACHINES

THE DYNAMO

You already know a lot about direct current motors and generators. When you read *Electricity*, NavPers 10622, you found that, in its simplest form, a direct current machine consists of a coil placed in a magnetic field. When direct current is forced through the coil, a TURNING MOTION RESULTS: electrical energy becomes mechanical energy. That's MOTOR action. On the other hand, if the coil is forced to turn, CURRENT IS PRODUCED: mechanical energy becomes electrical energy. That's GENERATOR action. This all adds up to one thing: D. C. MOTORS AND D. C. GENERATORS ARE REVERSIBLE MACHINES. Because they are reversible in action, they are tagged with the name of DYNAMOS. Figure 82 shows you a typical dynamo. It's a d. c. gas-driven generator used for small lighting requirements at advanced bases.

The d. c. motor produces mechanical energy, so its output is rated in HORSEPOWER. The d. c. generator produces electrical energy, so its output is rated in WATTS. These ratings are

important. They help you pick the motor or generator that will properly serve and meet the demands of a piece of equipment.

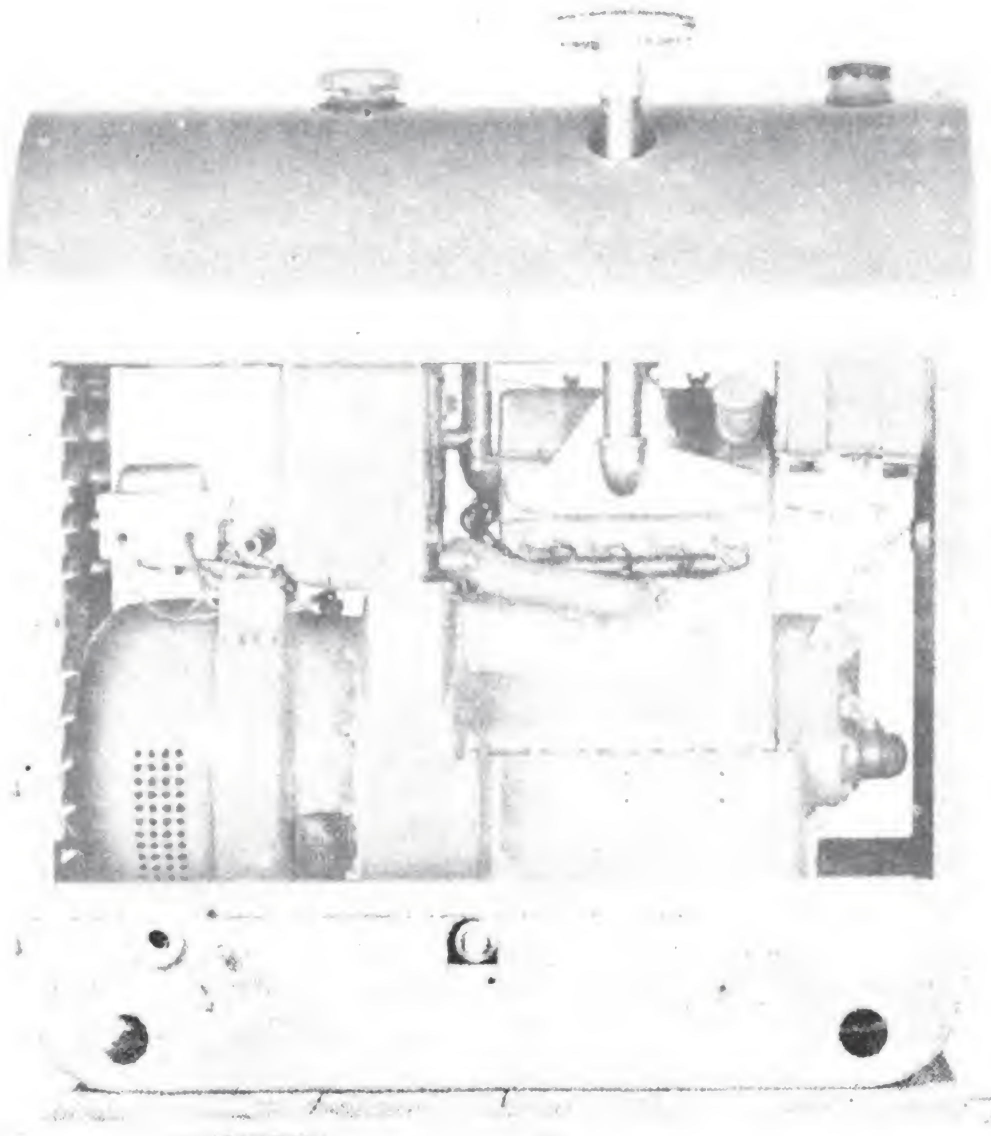


Figure 82.—A gas-driven d.c. generator.

DYNAMO CONSTRUCTION

There are many types of dynamos. Some are large in size, some are small, and some are designed for special jobs. When you get down to brass tacks, though, they all have the SAME

BASIC PARTS. The construction of the dynamo is easy to understand if you divide its basic parts into two sections: the MAGNETIC CIRCUIT and the ELECTRIC CIRCUIT.

The Magnetic Circuit

A magnetic field is a "must" for dynamo operation. The lines of force, which make up the magnetic field, must be directed and concentrated into the center of the dynamo. Figure 83 shows you how it's done.

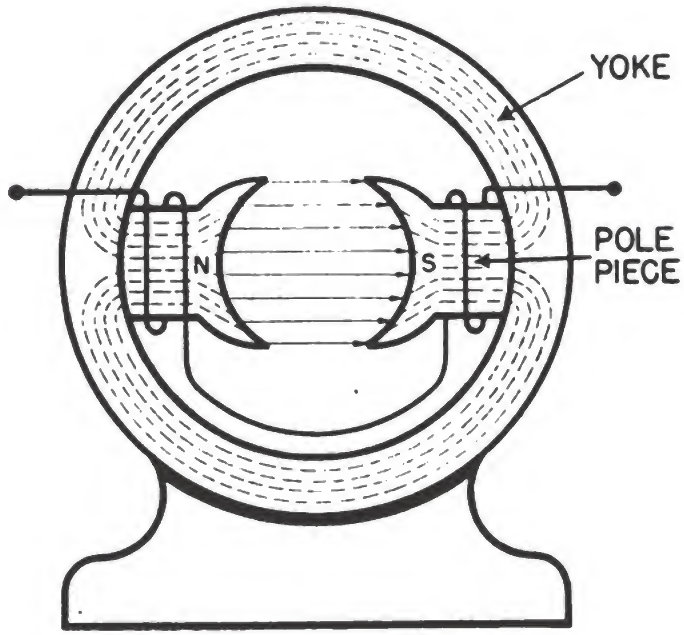


Figure 83.—The magnetic circuit.

The lines of force start at the north pole of an electromagnet. They travel through an air gap over to the south pole of the same electromagnet. They then return to their starting point through a circular steel frame, or YOKE.

The yoke has another job, too. It supports the POLE PIECES which form the core of the electromagnet. In large dynamos the pole pieces are separate parts which are bolted to the yoke. In small dynamos, however, the pole pieces and yoke are cast as one unit.

The pole pieces usually have a laminated structure. Don't let the word "laminated" throw you. It simply means that the pole pieces are formed from thin sheets of iron. Laminated pole

pole pieces are formed from thin sheets of iron. Laminated pole pieces improve the efficiency of the dynamo. A picture of a laminated pole piece is shown in figure 84. Notice the curved

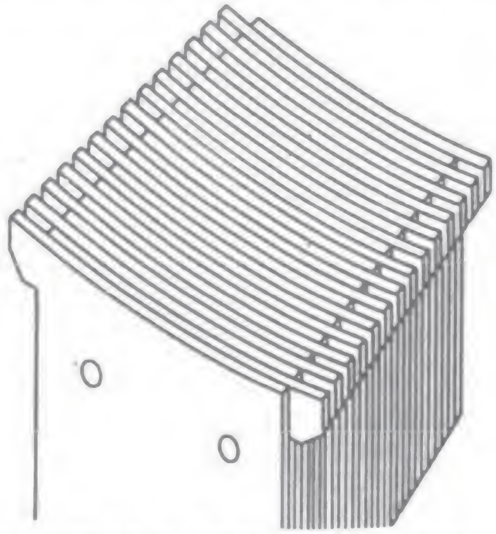


Figure 84.—Laminated pole piece.

end of the pole piece. It forms the edge of the circular air gap in the center of the dynamo. This curved end is known as the SHOE.

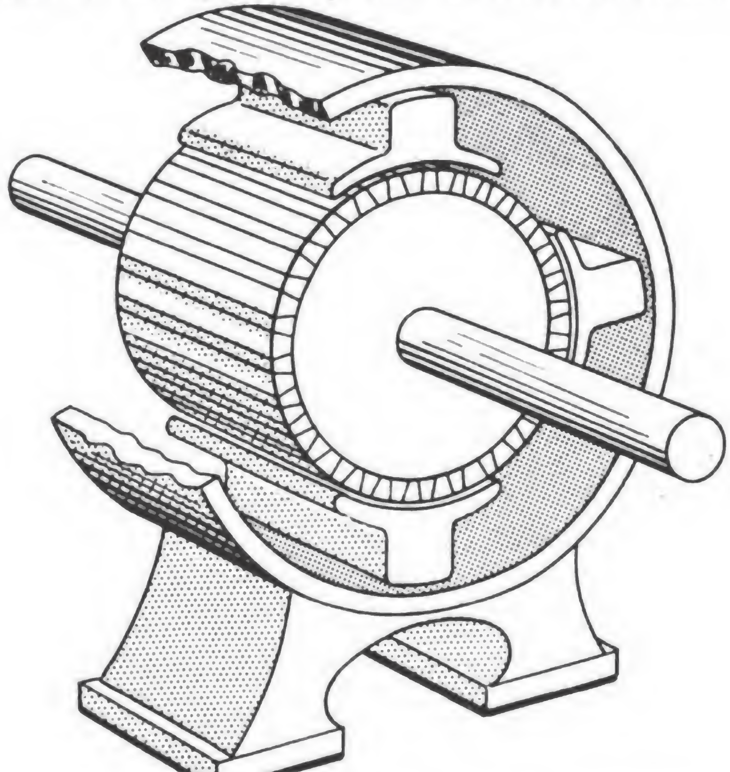


Figure 85.—Completing the magnetic circuit.

The magnetic circuit is completed when you place the ARMATURE CORE inside the air gap formed by the pole pieces. The armature core is laminated and cylindrical in shape. Figure 85 shows you the armature core mounted inside the air gap.

Figure 86.—End plate.

Notice that the armature core does not touch the pole pieces. This clearance, or air gap, is maintained by mounting the armature core onto a shaft. The shaft is supported at either end by END PLATES which are bolted to the yoke. An end plate is shown in figure 86.

The shaft and armature rotate at high speeds. If the shaft is seated directly into the end plate, high losses would result be-

Figure 87.—Bearing mounted in end plate.

cause of friction. This problem is overcome by using bearings. A bearing is fitted on each end of the shaft, and then seated in the end plates. You may use either the BALL BEARINGS or the SLEEVE BEARING. Figure 87 shows you a cross-sectional view of a ball bearing placed in the end plate.

The Electric Circuit

The magnetic circuit CARRIES, BUT DOES NOT PRODUCE, the magnetic lines of force. The FIELD COILS perform this job. The field coils are part of the electric circuit. Their construction is

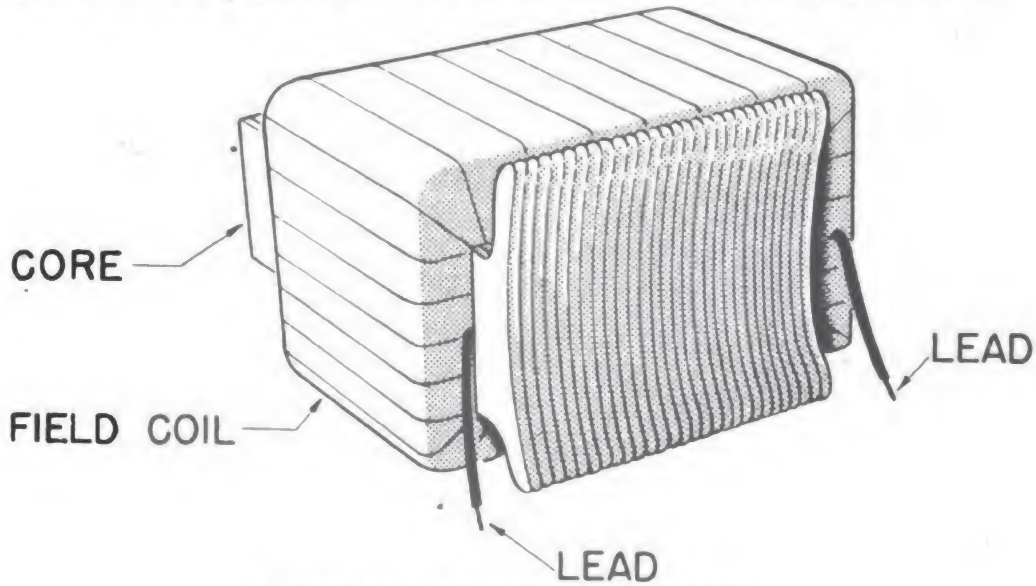


Figure 88.—Field coil on pole piece.

simple. Like any electromagnet they consist of a number of turns of enamel or cotton-covered wire. A wrapping of var-

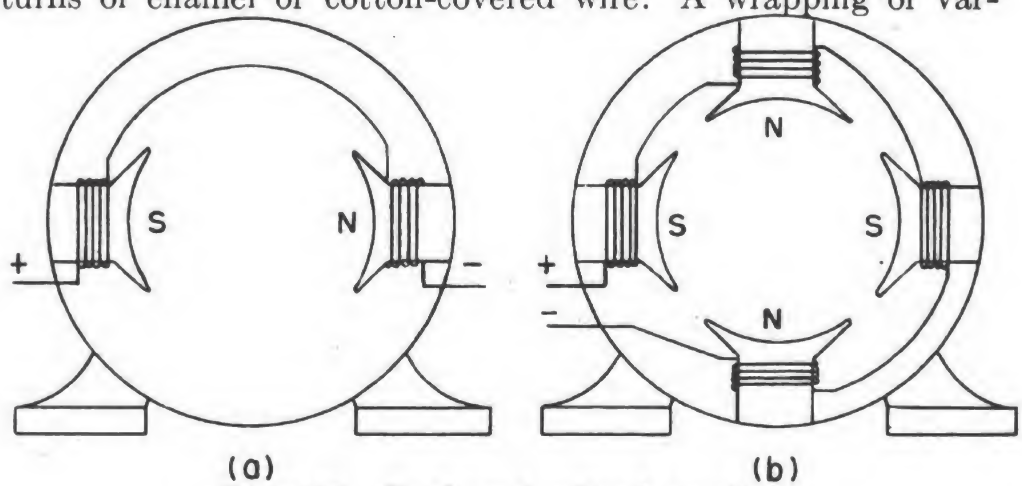


Figure 89.—Bipolar and multipolar machines.

nished cambric and cotton tape serves as insulation. Figure 88 shows a field coil placed over the pole piece which serves as the core of the electromagnet.

In the dynamo, a NORTH or SOUTH pole is formed from TWO field coils and TWO pole pieces. The field coils are connected in series with each other. A wiring diagram of this set-up is shown in figure 89.

The dynamo on the left has two pole pieces, so it's called a BIPOLAR machine. The dynamo on the right has four pole pieces, so it's termed a MULTIPOLAR (many pole) machine. You'll find that most small dynamos will be the bipolar type. The larger ones usually are the multipolar type.

The field coils are only part of the electric circuit of the dynamo. It's true they produce the magnetic field, but that's only half the picture. The ARMATURE WINDINGS, COMMUTATOR, and BRUSHES complete the picture. The armature windings are nothing more than coils of wire. Each coil is wound around the

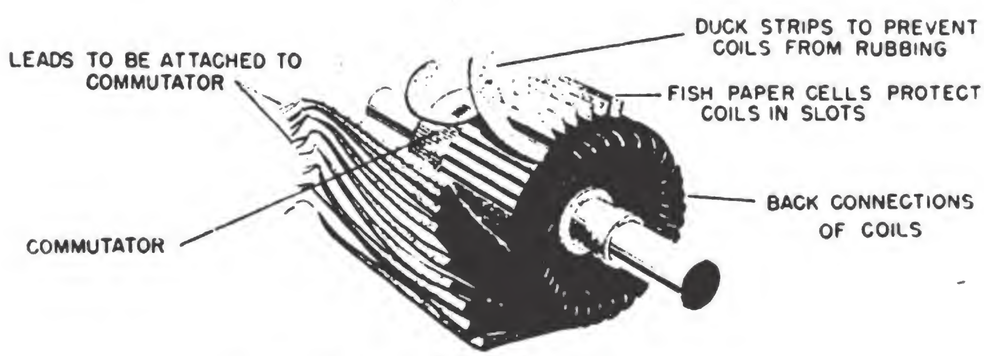


Figure 90.—Partially completed armature.

armature core. Figure 90 shows you the armature core with half its windings in place. Each winding is inserted in a slot on the armature surface. The armature core rotates at high speeds. Placing the windings in the slots prevents their being thrown off the core.

Since the armature windings are part of the electrical circuit, they must be insulated from the core. Take another look at figure 90, and you'll see that the slots are lined with thin insulating paper. Perhaps you are wondering about the position

of each armature coil. Coils aren't placed on the core in a random fashion. You'll find them so positioned that while one side of a coil is passing the north pole of a pole piece, the other side is sailing by the south pole—a perfect set-up for dynamo action.

The armature windings must be connected to the external circuit. When the dynamo is working as a d. c. motor, current from the external circuit is brought into the windings. When the dynamo is working as a d. c. generator, current from the windings is forced out to the external circuit. The armature windings rotate along with the armature core. You can see that no DIRECT connection is possible between the external circuit and the windings. You must employ SLIDING contact to bring the two together.

The sliding contact used in dynamos consists of two parts: the COMMUTATOR and the BRUSHES. The commutator is connected to the armature windings and rotates along with them. The brushes are connected to the external circuit and remain stationary. The brushes rest on the commutator surface. That's where the sliding contact comes in.

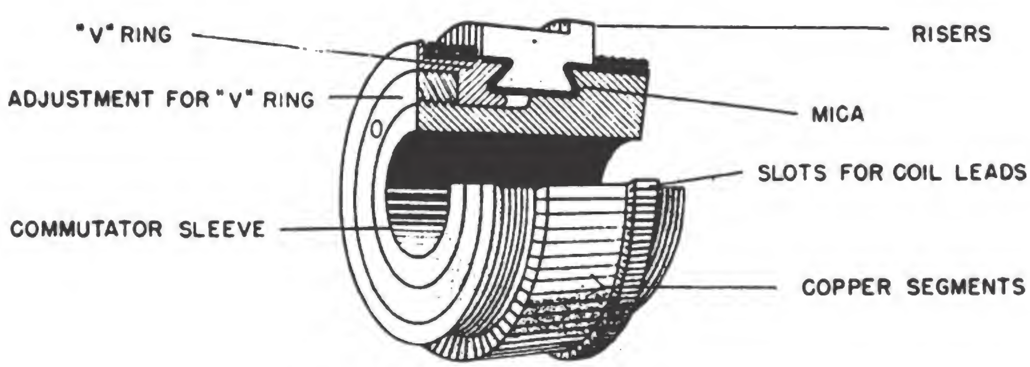


Figure 91.—Commutator construction.

The commutator is made up of separate COPPER bars, or segments. Each bar is mounted side by side, around an iron sleeve, and then clamped together. Figure 91 will help you to understand this construction.

Why is the commutator constructed of separate segments? It's all tied up with the job that the commutator has to do. Commutator action is FULLY explained in *Electricity*, NavPers

10622. BRIEFLY, this is the reason for its peculiar construction: ANY COIL which rotates in a magnetic field generates an ALTERNATING e.m.f. Every time a coil side moves by one pair of poles the current in the coil REVERSES its direction of flow. This applies to the armature windings in a d. c. generator. Therefore, the job of the commutator is to rectify or CHANGE the alternating current to direct current for the external circuit. As the current reverses its direction in the coils, the commutator automatically reverses the connections between the coils and the external circuit.

A d. c. motor must also have a commutator for proper operation. The motor torque, or turning force, must always be in the same direction if the armature is to rotate. This can only be accomplished if the current is REVERSED in the armature coils as they pass from one pole to another. A d. c. motor is supplied with direct current. Thus, the commutator has the job of converting this direct current into an ALTERNATING one. Its action is the same as for a d. c. generator: it automatically reverses the connections between the armature coils and the external circuit at just the right time.

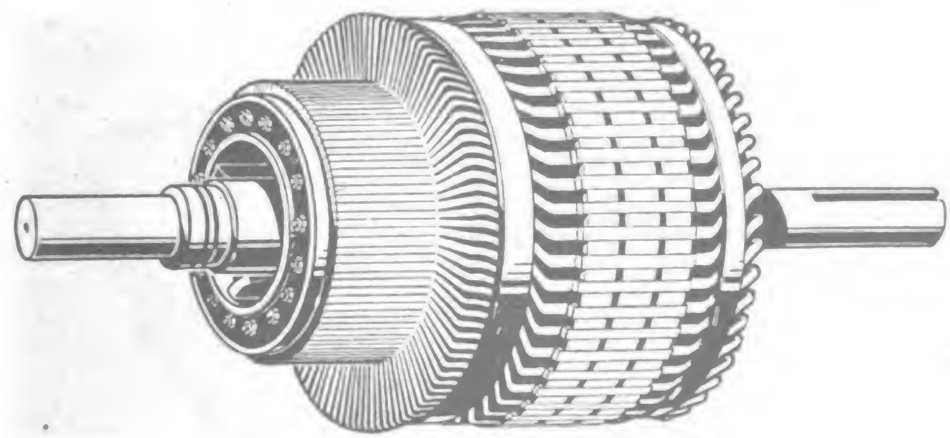


Figure 92.—A completed armature.

Each commutator bar forms part of the electric circuit of the dynamo. Therefore, the bars must be insulated from each other and from the iron sleeve on which they are mounted. Look closely at figure 91 and you'll see this insulation. It is made of thin sheets of mica.

Since the commutator rotates with the armature you'll find it mounted on the armature shaft. It is placed next to the armature core. The leads from the armature windings are then connected to each commutator bar. Each bar has a vertical lug known as the RISER. You can see the riser in figure 91. Notice the slot in the center of every riser. The armature leads are placed in these slots and soldered. A completed armature and commutator assembly is pictured in figure 92.

The BRUSH completes the electric circuit from the armature windings to the external circuit. Brushes are made in the form of solid carbon blocks. A typical brush is shown in figure 93. The bottom edge of the brush rides on the surface of the commutator. It is held in a stationary position by a BRUSH HOLDER. A SPRING holds the brush against the commutator and acts as an automatic feeding device. Continuous pressure keeps the brush in contact with the commutator as the brush wears shorter and

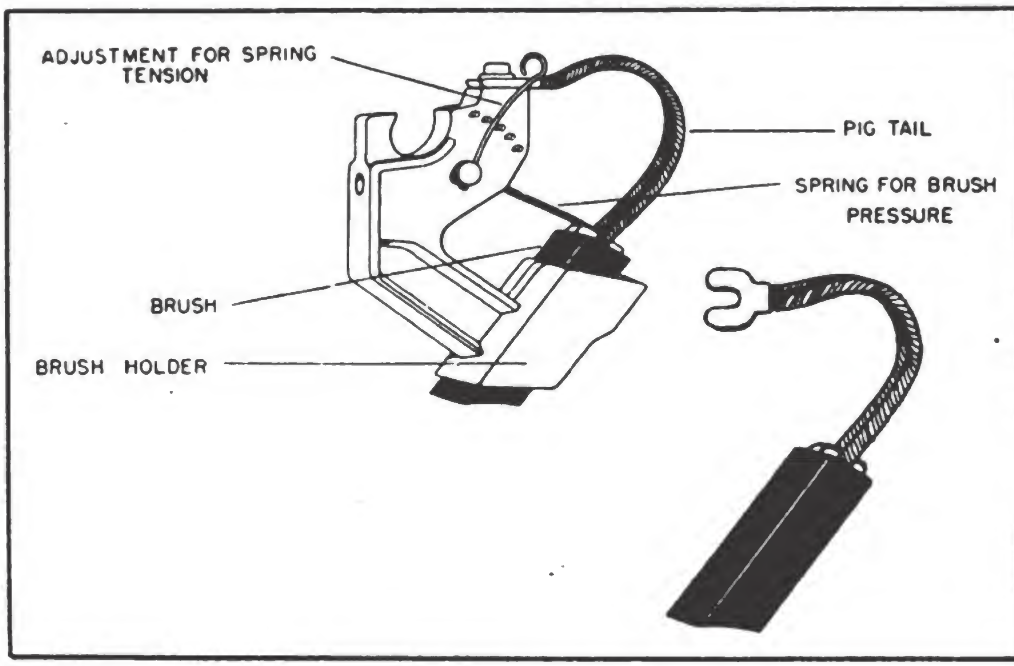


Figure 93.—Typical pigtail brush and holder.

shorter. The entire set-up is shown in figure 93. Notice that the spring pressure is adjustable. This allows you to set the proper pressure on the brush for maximum efficiency of operation.

In figure 93 you see a flexible copper lead, or pigtail, attached to the brush. When the brush is placed in the brush holder the unattached end of the pigtail is fastened to the brush holder. Current which flows from the armature windings to the external circuit must pass through the brush, pigtail, and brush holder.

Here's a question that may stump you. Why isn't the SPRING used to conduct the current from the brush to the brush holder? After all, one end of the spring is connected to the brush holder and the other end rests against the brush. The answer is simple. If current were allowed to flow through the spring, the metal would heat up and lose its elastic action. Result: no pressure on the brush, a break in the electric circuit, and the dynamo stops working.

The brush holder and the spring come under one heading: BRUSH RIGGING. The brush rigging is held securely in place by bolting it to the end frame of the dynamo. Since the brush

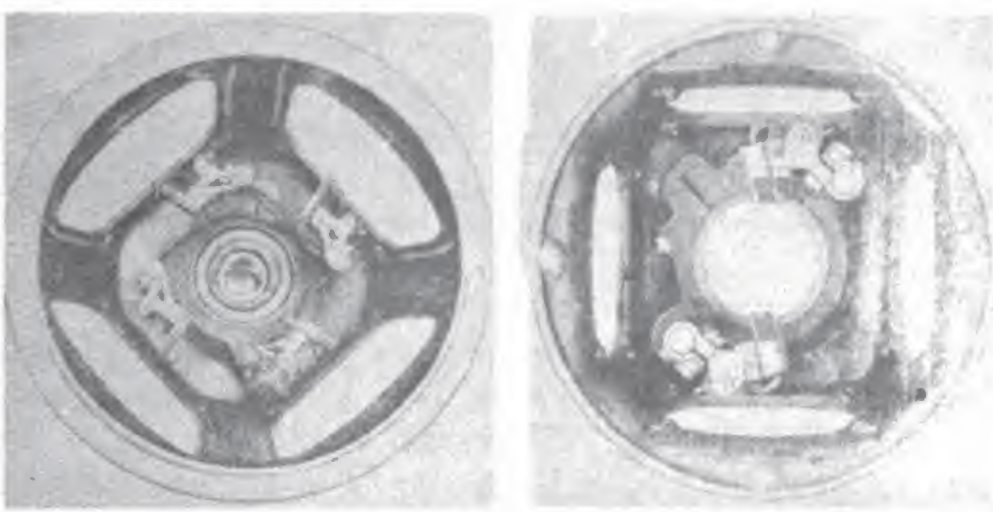


Figure 94.—Brush rigging attached to end frames.

rigging is part of the electric circuit it must be insulated from the frame. Figure 94 shows you two types of brush rigging attached to end frames. One end frame fits a dynamo using TWO brushes; the other fits a dynamo using FOUR brushes. You'll find that the number of brushes a dynamo uses depends

on the number of field poles it contains. A two-pole dynamo will have two brushes; a four-pole dynamo will have four brushes.

D. C. MOTOR CONNECTIONS

You've got the construction of the dynamo down pat, but what about the CONNECTIONS of the electric circuit? The electric circuit, you know, contains the field coils and the armature windings. They must be supplied with direct current if the dynamo is to operate properly. In a D. C. MOTOR this direct current is supplied from the external circuit. Since the field coils and the armature make use of the same current you shouldn't be surprised to find them connected together inside of the motor. And that is exactly what is done! In fact, d. c. motors are classified according to the method of INTERNAL CONNECTION between the field coils and the armature windings. For this reason, they are known as SERIES, SHUNT, and COMPOUND motors.

The Series Motor

Figure 95 shows you two diagrams of a series motor. Both represent the internal connections of the same motor. The diagram marked (*a*) is termed a wiring diagram. Diagram (*b*) is termed a schematic diagram. Be sure you are fully acquainted with the symbols because you'll use these diagrams throughout the chapter.

Suppose you trace the electron flow through the motor. The electrons start at the negative terminal of the external leads. They enter the armature winding through the brush and commutator. Then, leaving the armature winding by way of the commutator and the other brush, they flow through the field coils and over to the positive terminal of the external leads. The external leads, of course, are connected to the electrical power source which is delivering the current into the motor. The SAME current flows through the armature windings and the field coils. They form a SERIES circuit. A d. c. motor using this internal connection is known as a SERIES MOTOR.

Check figure 88 for a picture of a series field coil. It is made

up of a few turns of large diameter wire. A few turns of large wire means a low resistance coil. Put your knowledge of resistance in series to work and you'll see the reason for this. If the resistance of the field coils were high, it would reduce the amount of current flowing through the series-connected armature.

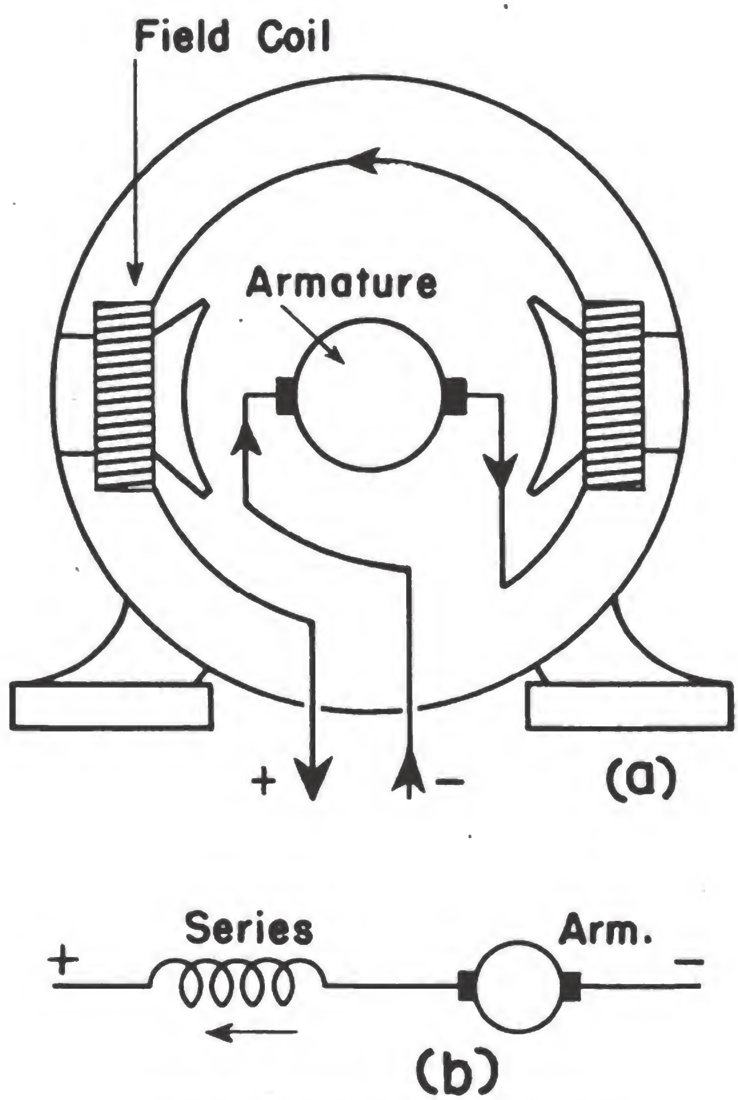


Figure 95.—Series motor connections.

The armature windings need a high current to produce the torque necessary for motor action.

A series motor isn't built just for its looks. The armature windings are placed in series with the field coils for a purpose.

It all has to do with the operating characteristics of the motor What does the term operating characteristics mean? Nothing more than the measure of the motor's ability to work under load. This ability is measured in terms of TORQUE (turning power) and SPEED.

Have you ever started a gas engine? It's as easy as pressing the starter button. But you know it isn't the starter button that gives the initial, terrific push to the engine. Do a little investigating, and you'll discover a series motor connected to the engine shaft. A series motor is used because it has a HIGH STARTING torque.

High starting torque is the chief advantage of the series motor. It has a disadvantage, too. Its speed VARIES as the load changes. In fact, the speed of a series motor operated with no load on its shaft becomes great enough to wreck the motor. That's why you'll always find a series motor connected by means of gears to the load it is driving. A pulley is never used since the connecting belt might slip off.

The Shunt Motor

A SHUNT MOTOR has its field windings placed in PARALLEL with the armature windings. Figure 96 shows you a two-pole motor with this type of internal connection. The field coil consists of a great many turns of small diameter wire. That combination means a high resistance and low current flow. But that's all right since a small current and many turns of wire will still produce a strong magnetic field. What counts is that the parallel connected armature windings get all the current they need for motor action.

Unlike the series motor, the shunt motor has a LOW STARTING torque. It has the advantage, though, of holding a fairly CONSTANT speed over a wide range of load changes. This speed characteristic makes the shunt motor a natural driving source for drill presses and lathes.

The Compound Motor

Compounding means combining together. If you combine the features of a series motor with those of a shunt motor you have a COMPOUND MOTOR.

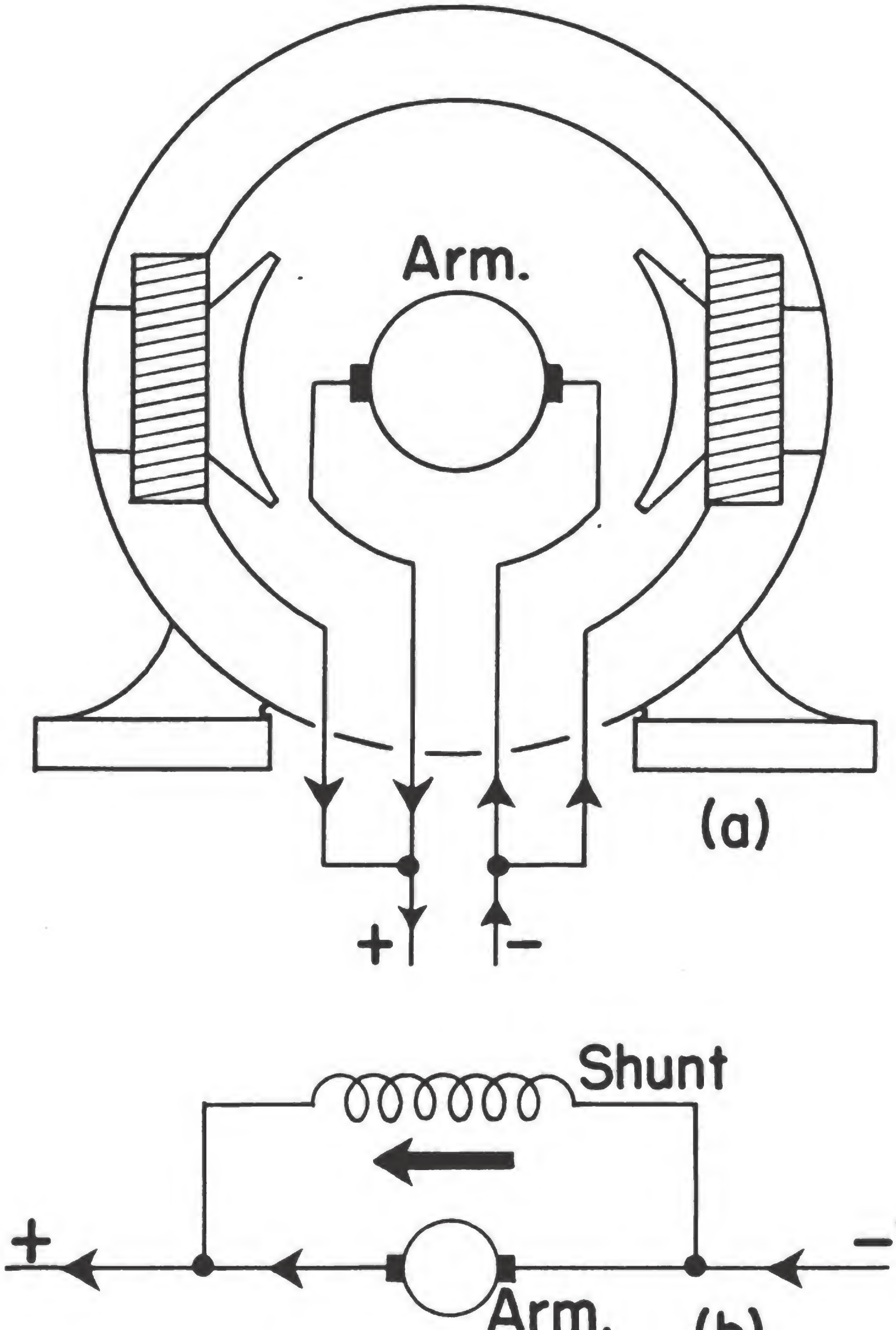


Figure 96.—Shunt motor connections.

The construction of the compound coil windings is just what you would expect: a series field coil and a shunt field coil mounted on every pole piece. The coils form separate circuits, one being connected in series with the armature and the other in parallel. Figure 97 shows you the connections in a schematic diagram.

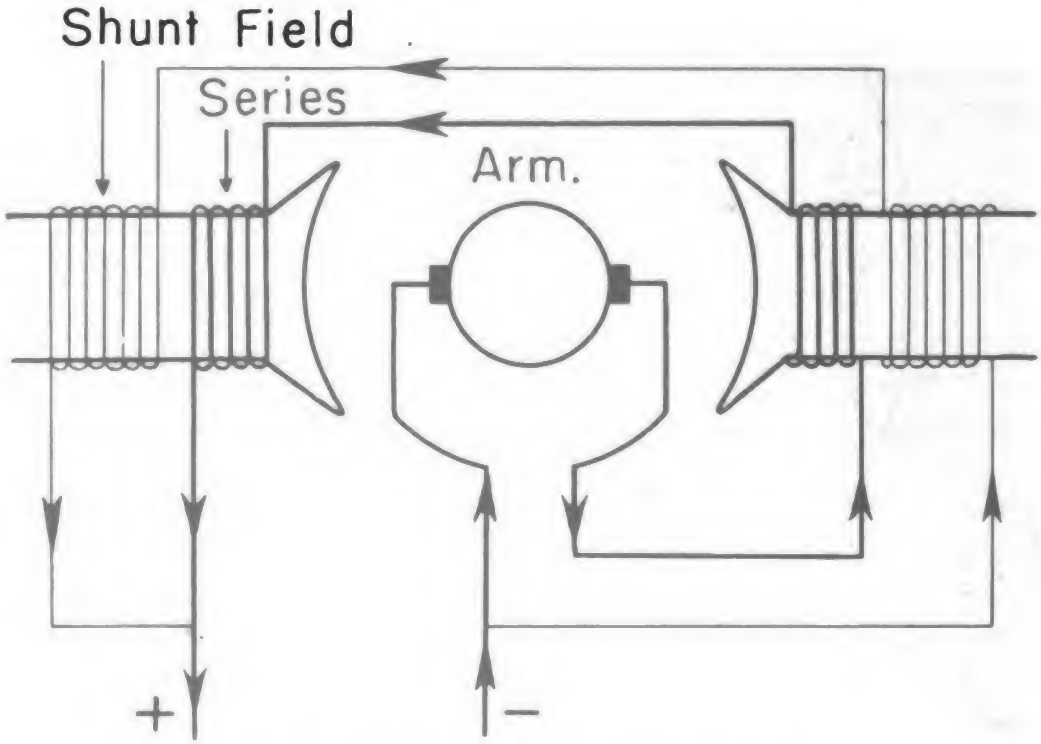


Figure 97.—Compound motor connections.

Since a compound motor is a combination of a series and shunt motor it will have some of the operating characteristics of each. You'll find that its starting torque is below that of the series motor but above that of the shunt motor. Its operating speed isn't as steady as the shunt motor but it will not reach the dangerous speeds of a series motor. To furnish driving power for pumps and machine tools is where the compound motor fits in best.

GENERATOR CONNECTIONS

Remember what was said about d. c. motors and generators? They are reversible machines. Therefore, it isn't surprising to

find that d. c. generators have series, shunt, and compound field windings, too.

How about operating characteristics? Are they the same for both the motor and generator? The answer, of course, is NO. The motor produces mechanical energy. Its operating characteristics are measured in terms of torque and speed. The generator produces electrical energy. Its characteristics are measured in terms of VOLTAGE REGULATION.

Voltage regulation is a measure of the generator's ability to deliver current with a change in load. The load, of course, is the lights and motors to which the generator supplies current. The change in load comes about as the lights and motors are turned on and off.

You can see voltage regulation in action. Suppose you are operating a generator which feeds a light circuit and a motor circuit. The lights are on and the motor is off. Then you switch the motor on. At that instant the lights dim. You know the reason for this. The generator just couldn't supply both the motor and lights with the proper current. The result is a drop in the generator output voltage.

The Shunt Generator

In a shunt generator the field is in parallel with the armature windings. A schematic diagram of this connection is shown in figure 98.

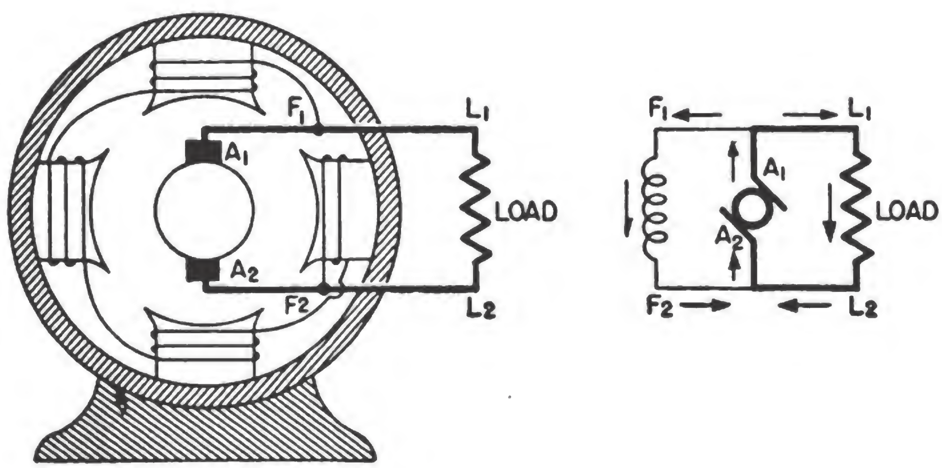


Figure 98.—Shunt generator connections.

The voltage regulation of the shunt generator is poor. That is, as the load increases to full value the generator output voltage falls rapidly. And this is the reason why. Notice that the shunt field, being in parallel with the armature, is directly across the generator output. Any increase in load tends to reduce the generator output voltage. A reduced output voltage cuts down on the shunt field current. A decrease in field current results in a decrease of magnetic strength. A low field strength means a corresponding drop in output voltage.

Because of its poor regulation, you won't find the shunt generator used to supply changing loads. Its greatest application finds use in the a.c. generator. Here it is used as a direct current source to feed or excite the field windings of the a.c. generator.

The Compound Generator

The COMPOUND GENERATOR has a shunt-field and series-field winding. Sounds familiar? It should, because you've read about this set-up in the compound motor. In this case, however, the series field improves the voltage regulation.

The series field carries the load current. When the load on the generator increases, the load current also increases. An increase in load current means a stronger magnetic field. This aids the weakened field of the shunt coil. Thus, a decrease in output is prevented. Result: very good voltage regulation.

MAINTENANCE AND MINOR REPAIR

Keeping a motor or generator in good working order isn't a hard job, but it is an important one.

Cleaning the Commutator

Remember what the commutator is? The commutator is just segments or bars of copper insulated from one another. Each copper bar is a part of the electrical circuit. When the commutator rotates, the bars pass under stationary brushes. This is a sliding contact. You don't need three guesses as to what happens when dirt gets on the commutator. The abrasive action of the dirt particles create small furrows or scratches on the soft copper surface. This results in poor contact between

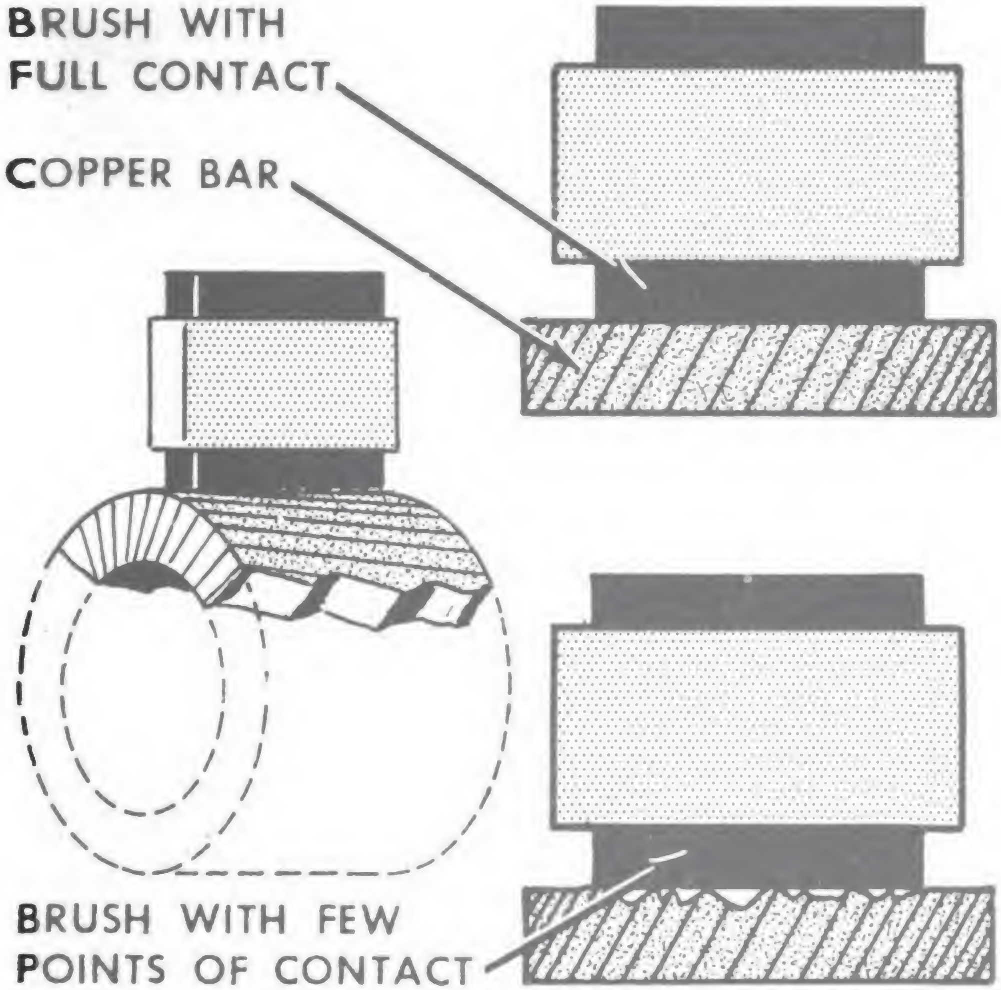


Figure 99.—Dirty commutator causes sparking.

brush and commutator as shown in figure 99. Poor contact means sparking and further pitting of the commutator surface.

Getting rid of commutator dirt is easy—if you use the proper tools and methods. Figure 100 shows you one way of doing it. The cleaning tool is merely a wooden stick with a piece of "00" sandpaper securely fastened to one end. The width of the wood stick is the same as the commutator being cleaned.

Place the dynamo in operation and hold the covered end of the stick lightly against the rotating commutator. Do this for a few seconds, then check the commutator surface. If it still isn't clear, repeat the procedure.

Here are a couple of DON'TS that you must observe. Don't use emery cloth. The hard emery material will scratch the com-

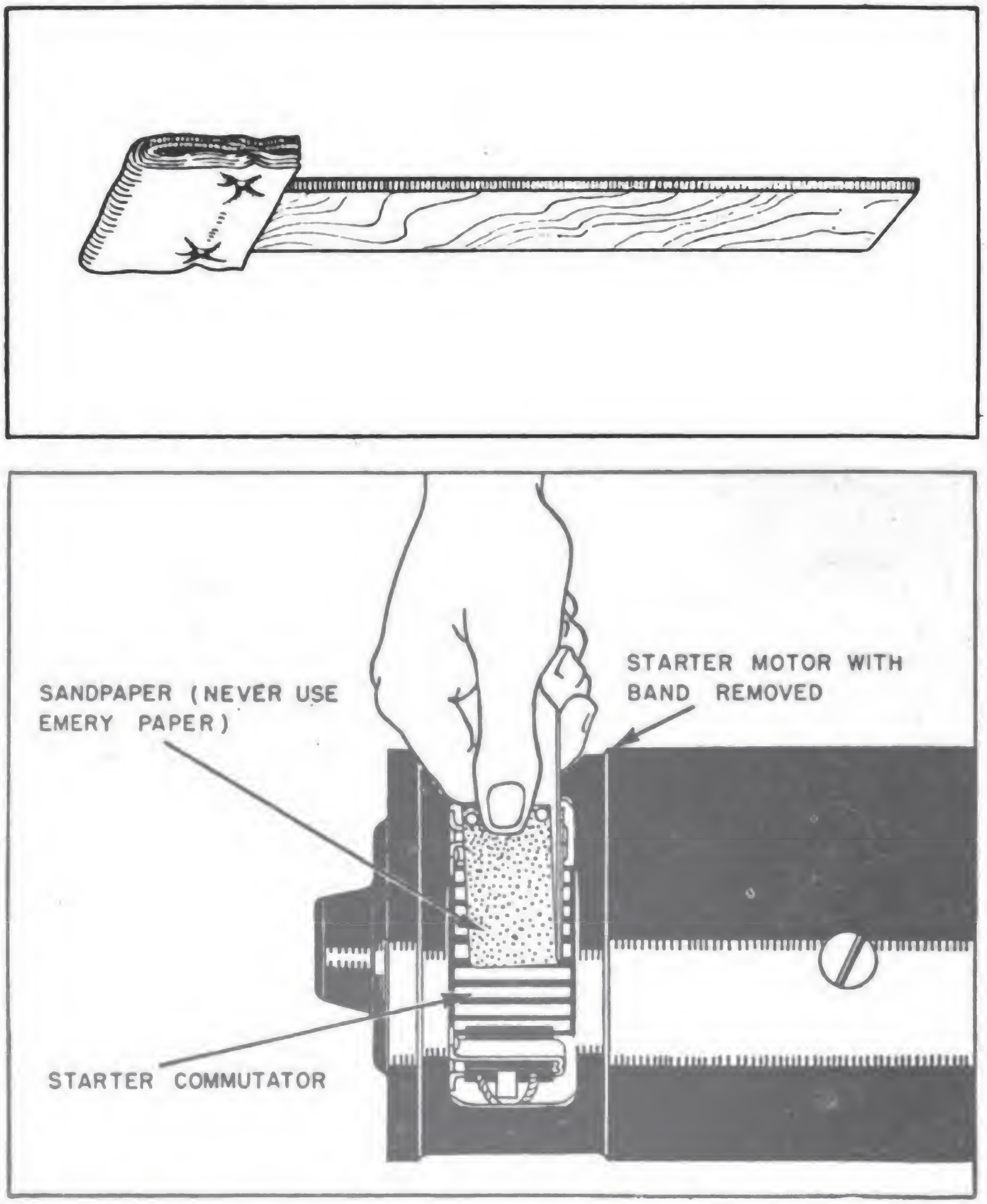


Figure 100.—Cleaning the commutator.

mutator surface instead of polishing it. Don't use a lubricant or gasoline to clean or polish the commutator. The lubricant will soak into the mica insulation between bars and change it to a conductor. Shorted commutator bars mean shorted and burned out armature windings. The gasoline is dangerous in other ways. Since the motor is in operation, there is always a possible chance for a spark to jump between commutator and brush.

You know that gasoline and open sparks don't get along together.

You must get rid of the copper dust which results from the cleaning operation. Use a piece of canvas as a dusting cloth. Better still, if available, compressed air can be employed to blow the dust from the hard-to-get-at-spots.

Checking the Brushes

Your weekly inspection should include a check on brush condition. Keep a careful eye on brush length. Never allow the brushes to wear down past one-half their original length. Figure 101 shows you why. A badly worn brush causes loose spring tension. Loose spring tension means improper brush pressure. Improper brush pressure causes sparking and commutator wear.

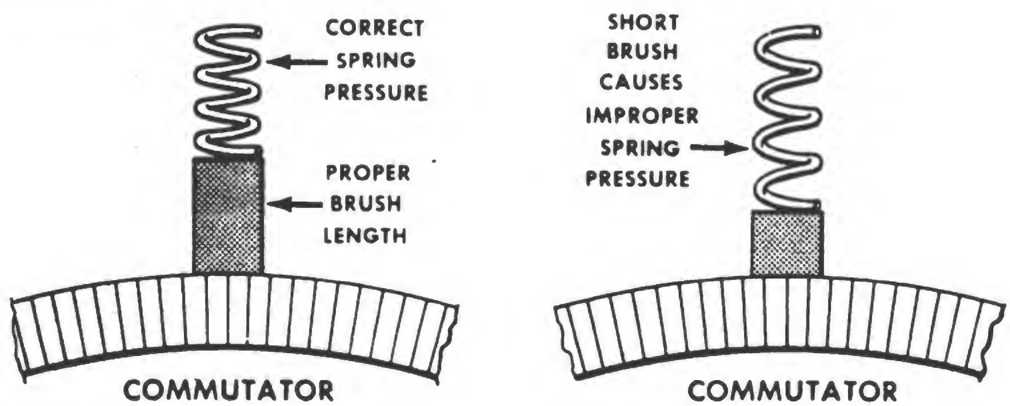


Figure 101.—Effect of worn brush.

Worn brushes must be replaced, and the replacing involves more than just the substitution of a new brush. First of all, the brush must be properly SEATED. Take a look at the bottom surface of a new brush. It's perfectly straight isn't it? Put that straight edge against the curved commutator and you lose a lot of surface contact. You must fit the brush to the contour of the commutator.

Figure 102 shows you one method of fitting brushes. A strip of medium-coarse sandpaper is placed on the commutator under the brush. The sandpaper should be as wide as the brush. Draw the sandpaper in the direction of rotation of the machine while applying pressure to the brush. LIFT the brush and return

the sandpaper to its original position for another pull. Do this until the brush seats perfectly against the commutator. When you slide the sandpaper be sure you follow the contour of the commutator. Lifting the edges will cause a rounding off of the brush tip.

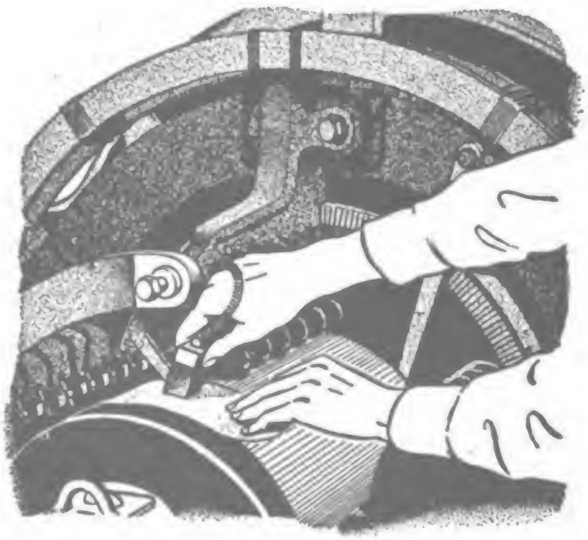


Figure 102.—Fitting the brush.

A good deal of carbon dust results from fitting brushes. Wherever possible, use compressed air to blow the dust out of the machine.

Adjusting the spring tension completes the job of replacing the brush. An ordinary spring balance may be used. The set-up is shown in figure 103. The balance is attached to the brush spring at the point where it contacts the brush. You exert a direct pull on the balance until the brush no longer rests against the commutator. At this point a reading of the balance is taken. This reading represents the pressure on the brush. A slip of paper placed under the brush can be used to determine the point at which the balance is read. When the slip of paper can be drawn from under the brush you know that the brush has left the surface of the commutator.

You should adjust the brush-spring pressure from 1½ to 2 pounds per square inch of brush. The exact brush pressure depends on the way the brushes react. Watch them. If they

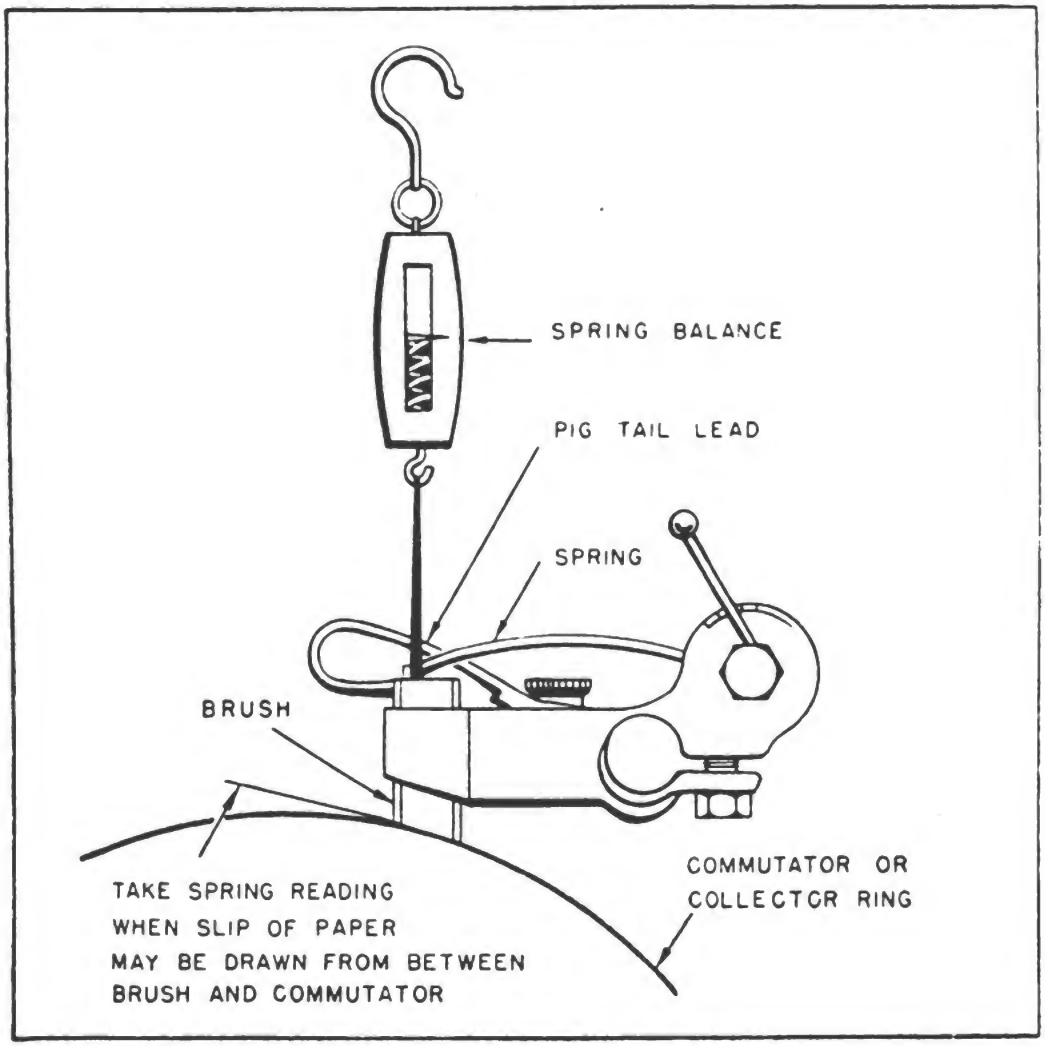


Figure 103.—Adjusting spring tension.

wear rapidly it means your spring pressure is too great. If there is excessive sparking it means the pressure is too light.

Sleeve-Bearing Lubrication

The bearings do a good job of reducing friction between the revolving armature shaft and the stationary frame. However, without oil and grease to help the bearings along, the dynamo just couldn't operate.

There are two main types of bearings used in motors and generators. One is called a SLEEVE BEARING and the other a BALL BEARING. Each requires a different method of lubrication because of its construction.

Take a look at figure 104. It shows you a sectional view of a sleeve-bearing in its housing. The bearing itself is made up of a metal sleeve which is mounted in the end frame of the machine. A shaft screw keeps the sleeve from turning. The inside surface of the sleeve is sometimes coated with a soft tin alloy known as BABBITT—especially on large units.

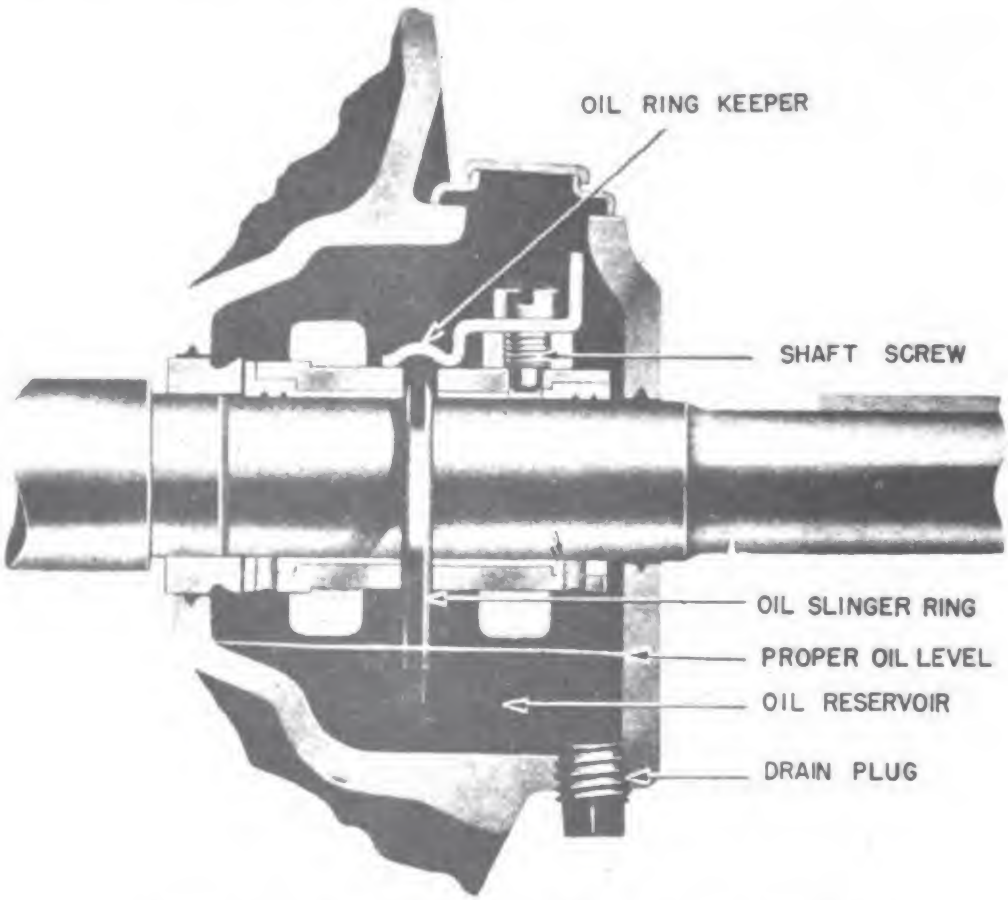


Figure 104.—Typical sleeve bearing—oil ring lubricated.

The armature shaft fits in the sleeve bearing, and rests right on its inside wall. How does that eliminate friction? It doesn't! In fact, the metal-to-metal contact creates a lot of friction, but only at the moment of starting.

Notice that oil slinger ring? The top rests on the shaft and the bottom dips into a pool of oil. When the shaft rotates, the oil ring turns with it. This action slings the oil up and out of the pool onto the moving shaft. The oil creeps along the shaft and forms a thin film BETWEEN the rotating shaft and the

stationary bearing. Can you think of a more effective way to reduce friction?

Where do you come in on this set-up? Well, just think what would happen if there were no oil in the reservoir for the oil ring to pick up. The heat produced by friction would actually melt the soft lining of the bearing. The molten metal would attach itself to the armature shaft just like a solder job. If the machine were brought to a quick stop the metal would cool rapidly and form a solid wall between shaft and bearing. Then you have a frozen bearing and a job on your hands.

It's up to you to maintain the proper level of oil in the bearing housing. A filler pipe is usually provided as a means of introducing the oil into the bearing housing. There may or may not be a gage. The point is, don't fill to overflowing. Figure 105 shows you the correct level for various types of oil gage.

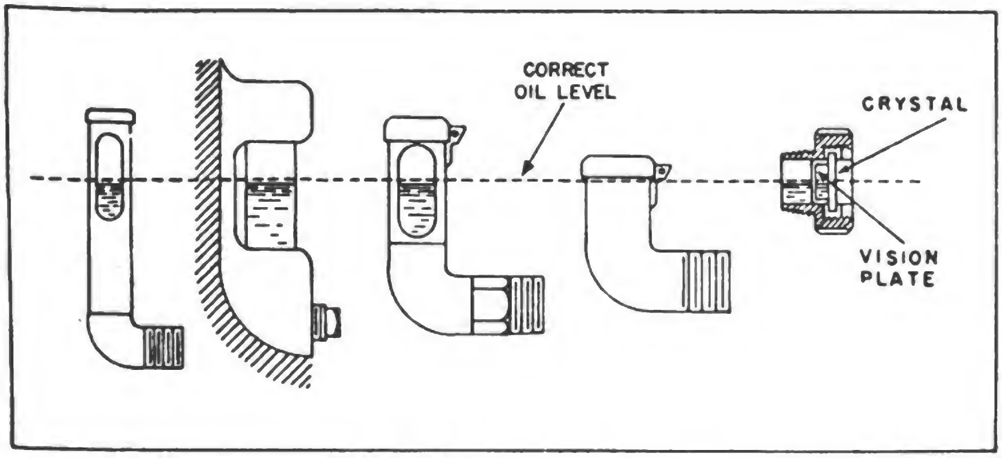


Figure 105.—Correct oil level for different types of gage.

Use a good lubricating oil. An average machine requires a 10-weight oil. This corresponds to Navy symbol 2110.

If you suspect that dirt has entered the bearing housing, you must drain the oil out. Remove the drain plug (figure 104) and allow the old oil to drain out. Then flush out any remaining dirt with new oil. Replace the drain plug and refill with new oil.

Ball-Bearing Lubrication

Figure 106 shows you the side view of a ball bearing. It also gives a clear picture of how the bearing looks when mounted in

the end frame of the dynamo. You can easily see how its construction differs from that of the sleeve bearing. First of all, it is much smaller in length. It is made up of an outside cylinder, called the OUTER RACE, an inside cylinder termed the INNERRACE, and a series of steel BALLS between the outer and inner races.

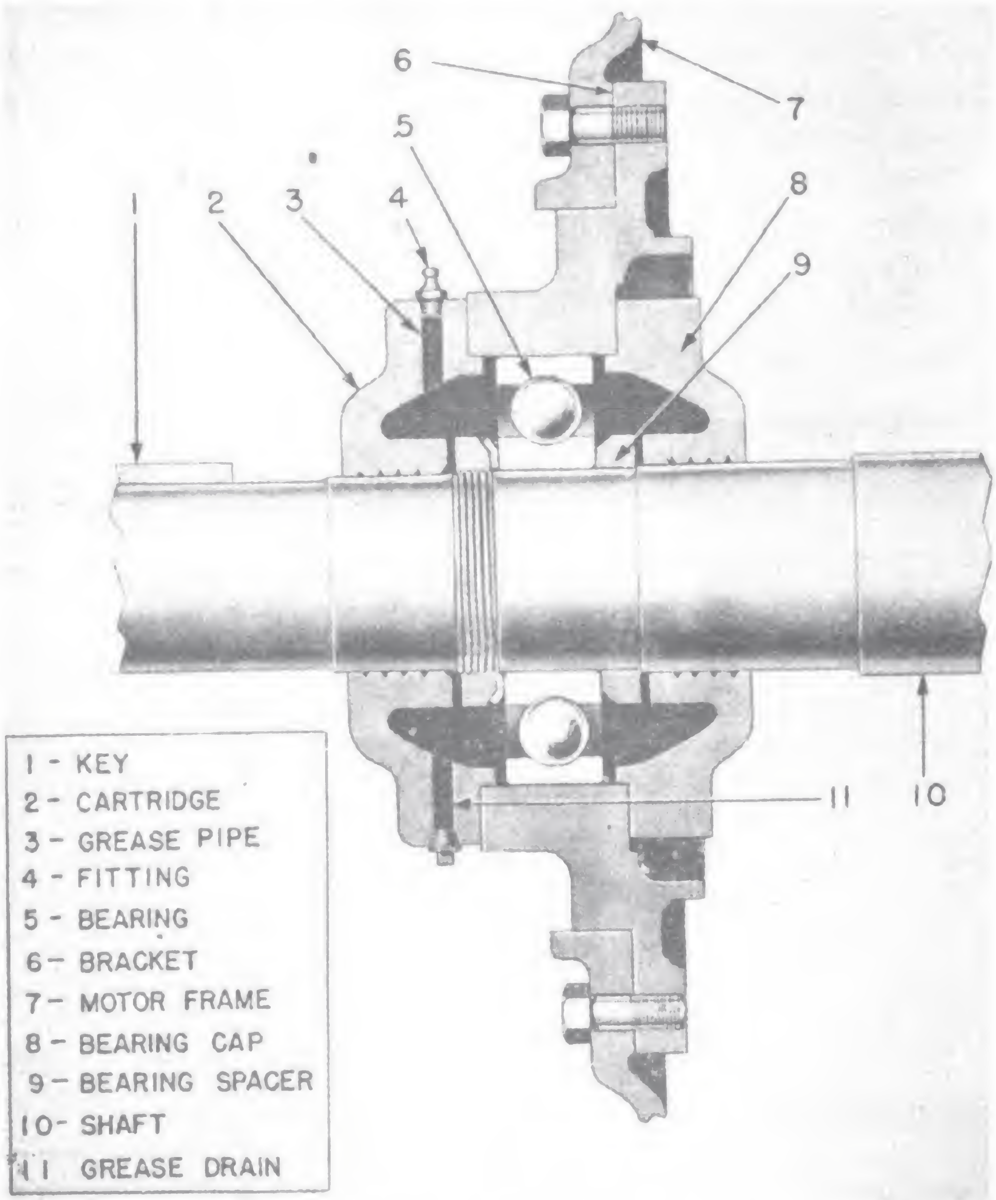


Figure 106.—Typical ball bearing—grease lubricated.

The outer race, which is stationary, presses against the frame of the motor. The inner race fits tightly over the armature

shaft and rotates with it. The steel balls roll around between the two races as the shaft turns, and reduce friction when the dynamo is in operation.

Remember that film of oil in the sleeve bearing? It acted as the friction-reducer when the dynamo was in operation. Well, the balls of the ball bearing take the place of this film of oil. They have one advantage which the film of oil doesn't have. The balls are always there, ready to reduce friction at the moment the dynamo STARTS. The film of oil in the sleeve bearing, however, appears only AFTER the dynamo begins to turn. Generally, ball bearings require grease instead of oil to further reduce friction. The grease used is Navy grade II lubricant, ball and roller bearing. Its Navy specification number is 14L3. When you lubricate a ball-bearing machine, remember that too much grease is as bad as none at all. That extra amount will cause overheating.

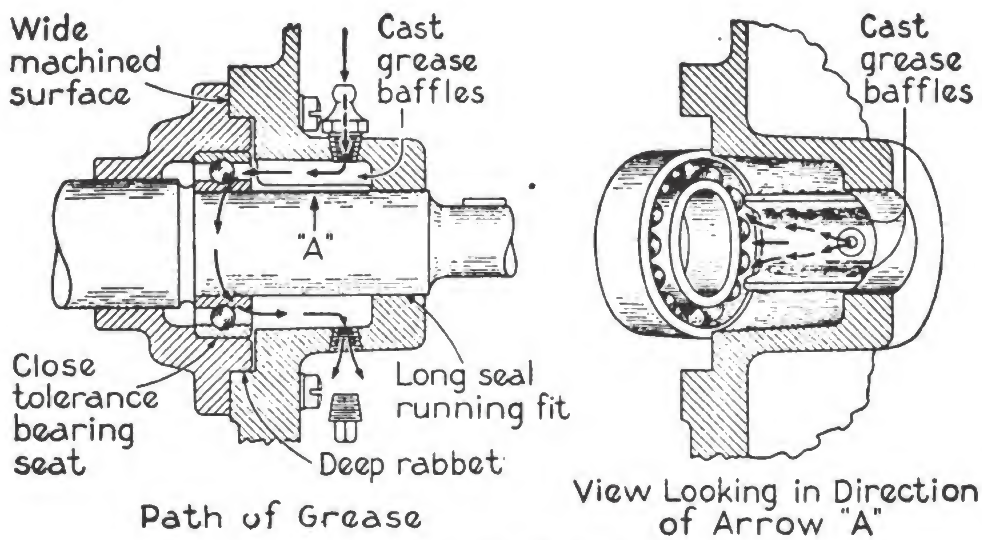


Figure 107.—Flow of grease in bearing housing.

Some machines use the pressure-relief method of greasing. If it's done right, there's no chance of overgreasing. Figure 107 shows you how this system operates. The arrows indicate the path which the grease takes. You force the grease in at the top, pushing out the old grease at the bottom. It's the relief hole at the bottom which prevents over-greasing. Any extra grease comes out there.

Figure 108 shows you the six steps in greasing ball bearings with a pressure gun.

Step 1 is just a common sense step. The bearing housing and pressure-gun fitting are wiped clean of dirt. Next (step 2) you

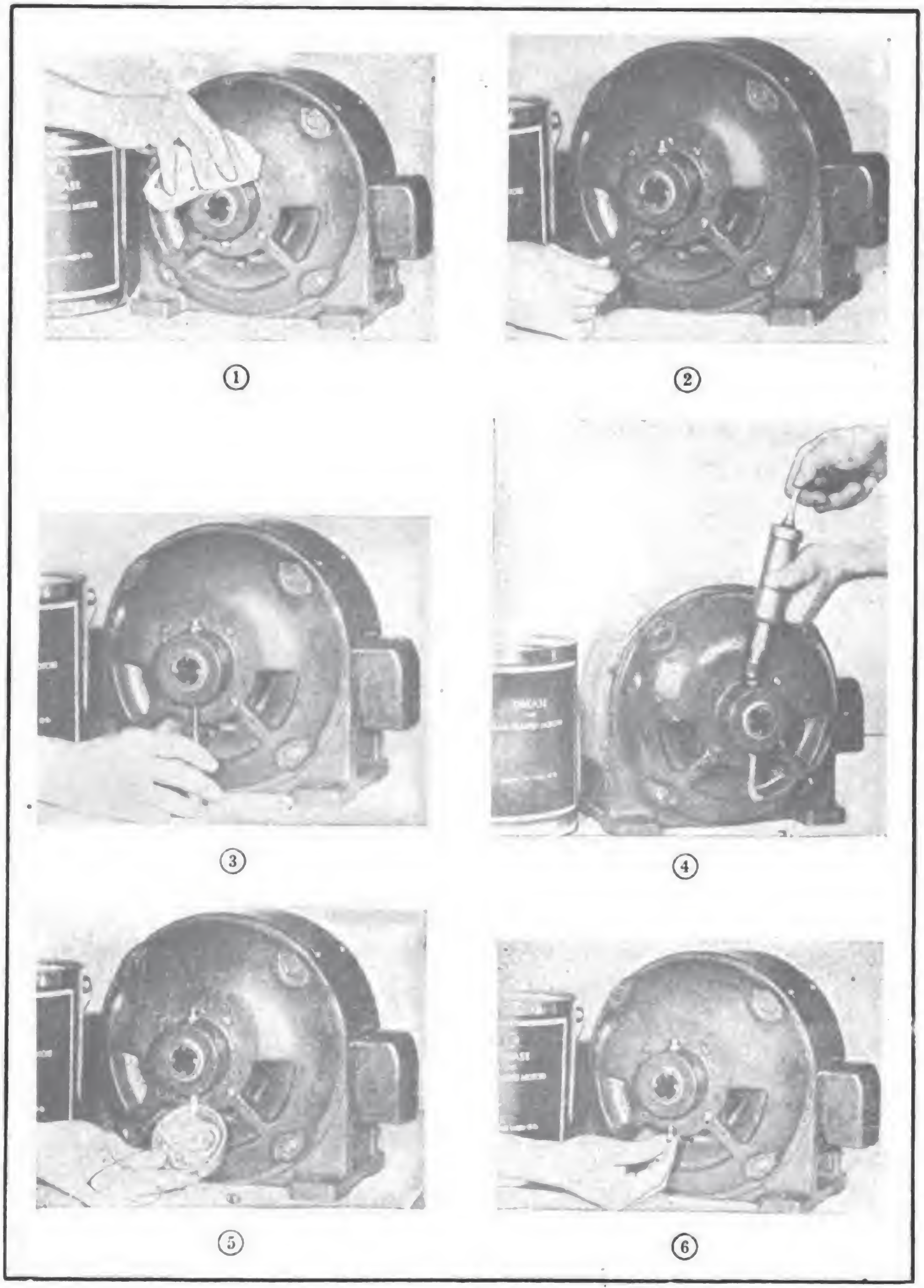


Figure 108.—Pressure gun method of greasing.

remove the relief plug at the bottom of the housing. Then clean the relief hole of any hardened grease (step 3). A screw driver comes in handy for this operation. In step 4 you apply the pressure gun and force grease into the bearing chamber. Continue to add grease until the new excess grease begins to ooze out of the relief hole. You should perform this operation with the machine running. Step 5 shows the pressure gun removed. The motor is allowed to run for a few minutes. This will expel excess grease from the rotating parts of the motor. Step 6 completes the job when you replace the relief plug.

Cleaning the Bearings

It may be necessary to clean the bearing. If the machine is equipped with the pressure-relief system, there is nothing to it. All you have to do is run a grease-dissolving solution through the housing. It's done in five steps, as shown in figure 109.

Wipe the housing clean and remove the pressure and relief fittings. Your first step consists of freeing the pressure-fitting hole of hardened grease. In the second step the relief hole is cleaned out.

Now, you're all set to introduce the grease dissolver. Either a light mineral oil (heated to 165° F.) or carbon tetrachloride may be used. Carbon tetrachloride is the better of the two, but you must take certain precautions. The fumes of carbon tetrachloride are poisonous. Be sure the workroom is well ventilated. Don't allow any of the carbon tetrachloride to splash on the windings. It will destroy the insulation.

Step 3 shows the grease dissolver being added into the bearing housing. The motor should be running during the operation. As the grease is dissolved it will drain out through the relief hole at the bottom. Continue to add the grease dissolver until it runs quite clear (step 4). Replace the relief plug and add grease dissolver until it can be seen splashing in the filling hole. Let it churn for a few minutes, then open the relief hole and drain. Continue this churning process until the grease dissolver runs clean (step 5).

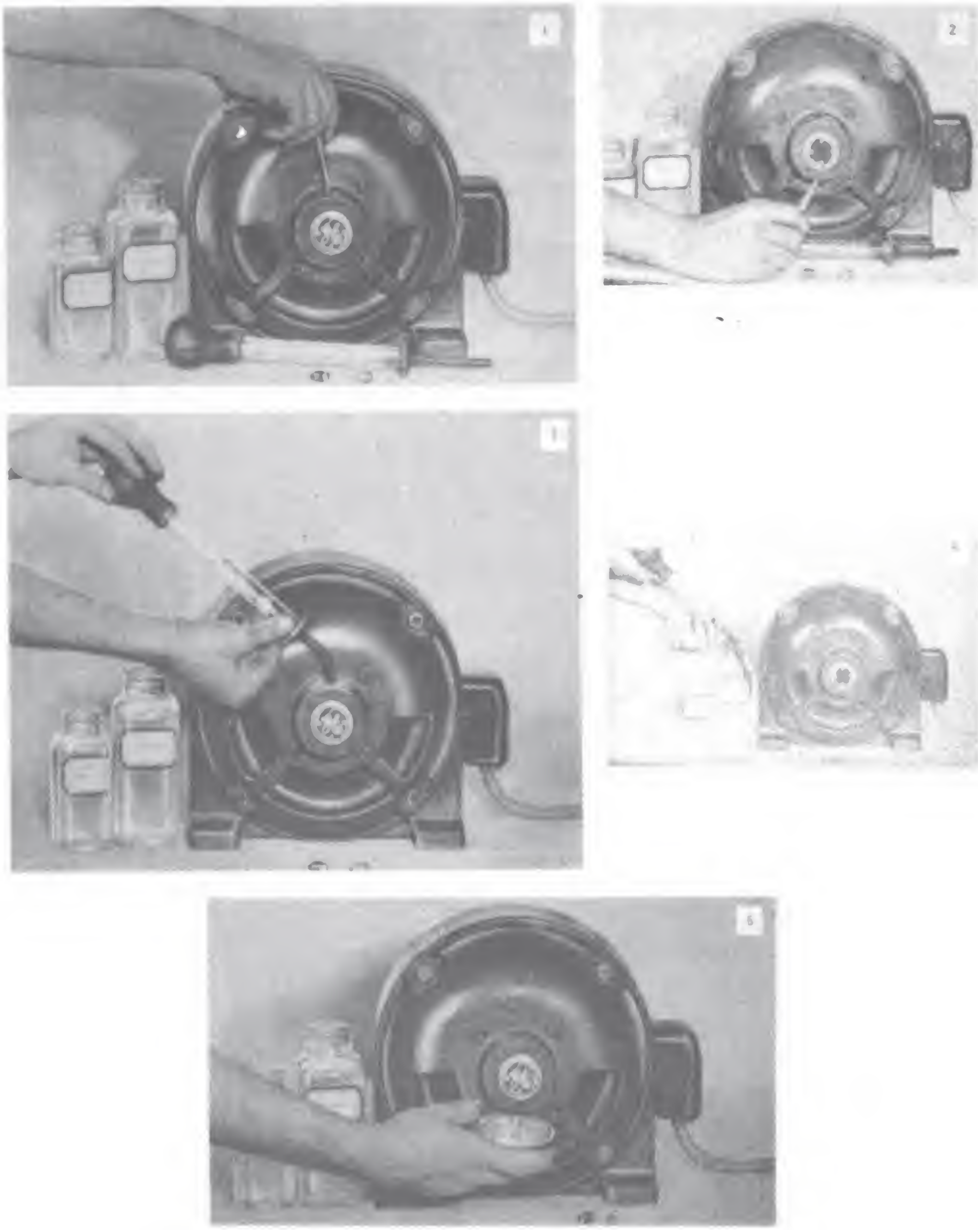


Figure 109.—Cleaning ball bearings.

Replacing the Bearings

Bearings eventually wear out. That means replacement. To get at the bearing you must, of course, dismantle the machine. This involves removal of the end plates and the armature.

Now, here is the order in which the machine is dismantled:

1. Remove the field terminal leads from the brush holders.

2. Tag all leads so that reassembly won't be guesswork.

3. Remove keys, pulleys, pinions, and fans.

4. Remove the end plates. They are either bolted to the dynamo frame (large machines) or held together with through bolts (small machines). Use punch marks for correct reassembly.

5. Slide the armature out. Be careful that it doesn't rub against the field coil winding. The ball bearings usually remain on the armature shaft.

Don't expect the bearings to slide off the shaft. They have a tight fit and must be forced off. The best tool to use is a bearing puller. A picture of it is shown in figure 110. Notice those claws which hook over the bearing. When you turn the threaded shaft those claws climb right up the shaft bringing the bearing with them.

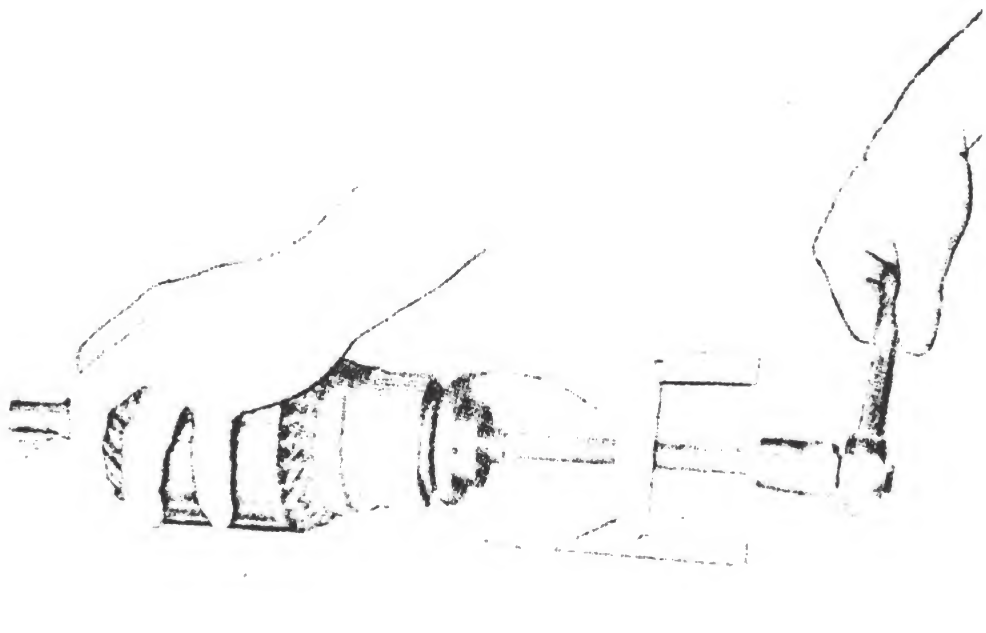


Figure 110.—Using the bearing puller.

Once the bearing is off the shaft, examine it carefully. Hold it at the center and give the outer race a spin. If the bearing appears to roll roughly, or sloppily, replace it. If all it needs is a cleaning, then dip it in carbon tetrachloride. Rotating the

bearing while it's in the cleaning solution will help. Dry the bearing in air and lubricate it with ball-bearing grease.

You've got to handle bearings gently. Not with kid gloves, but with canvas ones. Perspiring hands will cause corrosion on the bearing surface. Also, make sure not to scratch or nick the bearing. Use clean rags to wipe them. Your best bet is to leave new bearings in their packages until you're ready to install them.

Replacing a bearing on a shaft calls for a lot of care. Never pound or hammer the bearing directly. And don't apply pressure to the outer race. If you do it will result in a bad bearing and a scored shaft. Figure 111 shows you the right way and the results of doing it the wrong way.

WRONG ▶
Bearing should not be forced on shaft by means of the outer rings. It should not be forced on a badly worn shaft, or a shaft that is too large.

RIGHT ▶
Bearing is proper size for shaft and is being tapped into place by means of a metal tube that fits against the inner ring.

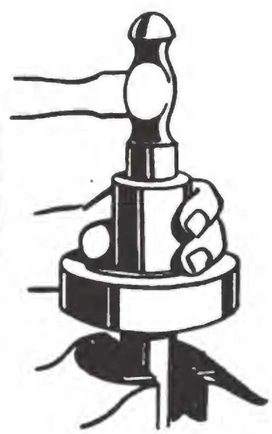


Figure 111.—Replacing the bearing.

ARMATURE COIL WINDINGS

It's your job to lend a helping hand in the winding, insulating, and baking of armature coils. Therefore, you should be familiar with types of winding and the material used in their construction.

Coil Facts

First of all, get the types of winding straight. There are two: LAP winding and WAVE winding. The difference between them is the manner in which the armature coils are connected to the commutator.

Take a look at figure 112. It shows a simplified drawing of two armature cores. Armature *A* has a lap winding, armature *B* a wave winding. Notice the way the coil ends are connected to the commutator bars.

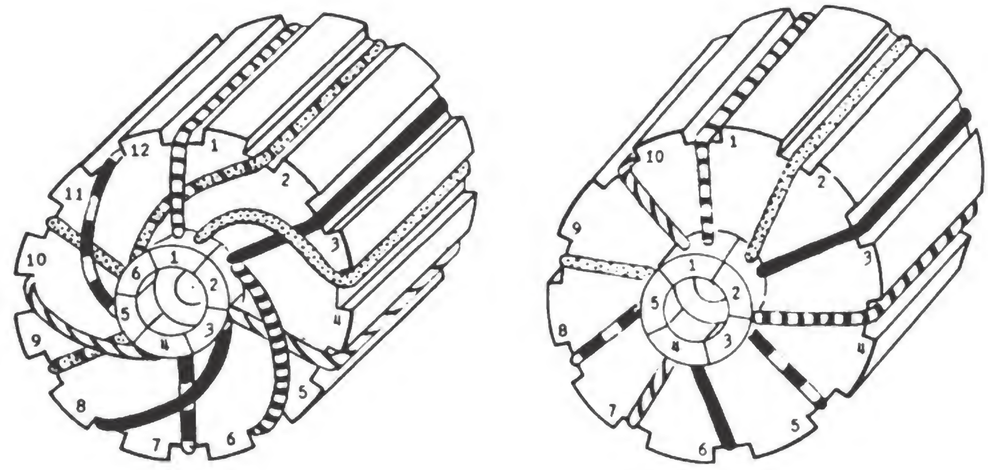


Figure 112.—Lap and wave windings.

On armature *A*, a coil starts at commutator bar No. 1. It travels through slot 1 of the armature, down the back of the armature, through slot 5 and ends up at commutator bar 2. The next coil starts at bar 2 and ends up at bar 3. Thus, you can see that the end lead of the first coil connects to the beginning lead of the next coil. All of the coils are in series with each other. This method is called lap winding because the coil leads lap over each other.

On armature *B* you have a different story. A coil starts at bar 1, goes through slot 1, through slot 4, and ends up at bar 3. The next coil starts at bar 2 and ends up at bar 4. Instead of connecting to adjacent commutator bars, the coil leads are attached to more widely separated bars. Because the arrangement of coil leads looks like a wave pattern, this method is called wave winding.

Here are a few facts you should get straight. First, the windings shown in figure 112 are basic types. They are called SIMPLEX windings because there is only one set of coils. You may run across an armature with two separate sets of coils.

This is called DUPLEX winding. A TRIPLEX winding has three separate sets of coils. Using extra windings increases the current capacity of the machine.

Second, some armatures have more than one coil placed in a slot—sometimes as many as three. In that case, you will find more commutator bars to take care of the added coil leads.

Third, figure 112 shows only one line in each slot. Actually that line represents a coil with many turns. The number of turns of wire in each coil, and the size of wire used, depends on the output desired from the machine.

Fourth, each armature is wound with a definite coil span. Coil span is the distance between the sides of any one coil. Armature *A* in figure 112 has a coil span of five. Armature *B* has a coil span of three. The coil span depends upon the distance between two adjacent poles of the motor or generator. This distance is called POLE PITCH.

The coil span is made very nearly equal to the pole pitch. It's not hard to understand why. Motor and generator action depend on one coil side being under a north pole while the other side is under a south pole.

Winding Procedures

The armature coils must not touch any part of the iron core. Thus, before any winding begins, you must insulate the core. Figure 113 shows an empty core ready to receive the armature coils. The slots are lined with fish paper or fiber paper as insulation. Figure 113 also shows the insulating tape which is applied to the shaft and the fiber washers which cover the ends of the core. This insulation is necessary to protect the coil leads which travel around the core and over to the commutator bars.

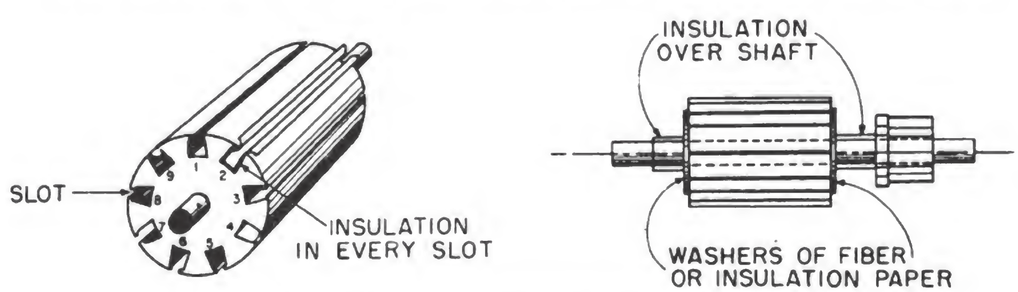


Figure 113.—Armature insulation.

Small armatures can be hand wound. Figure 114 shows you one coil being placed in the slots. If the armature is too heavy to hold, it may be placed on supports. This method is also shown in figure 114.

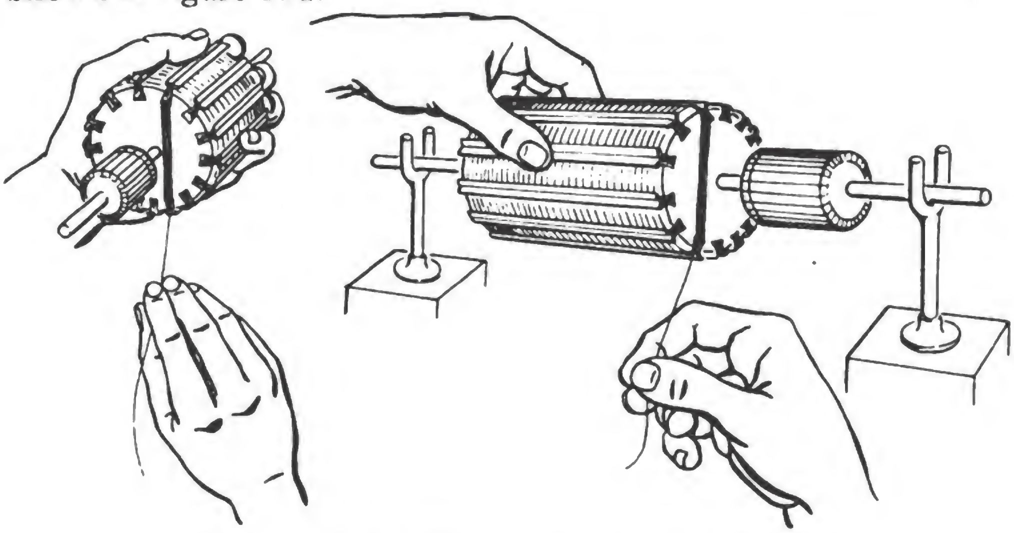


Figure 114.—Winding armatures by hand.

Larger machines use a form-wound coil. The coil is wound on a special form and then shaped to fit smoothly into the armature slots. Different types of formed coils are shown in figure 115.

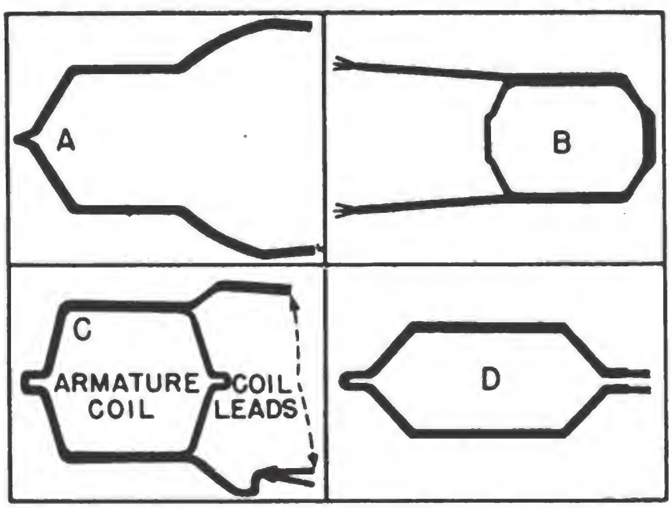


Figure 115.—Types of formed coils.

These coils are insulated with a cotton or varnished-cambric tape. The tape may be applied by hand or machine. Figure 116 shows one of the coils being taped by hand. After taping, the

coils are heated in an oven. While still hot they are dipped in a baking varnish. The coils are then placed back in the oven and baked dry. This provides a smooth varnish-insulated cover.

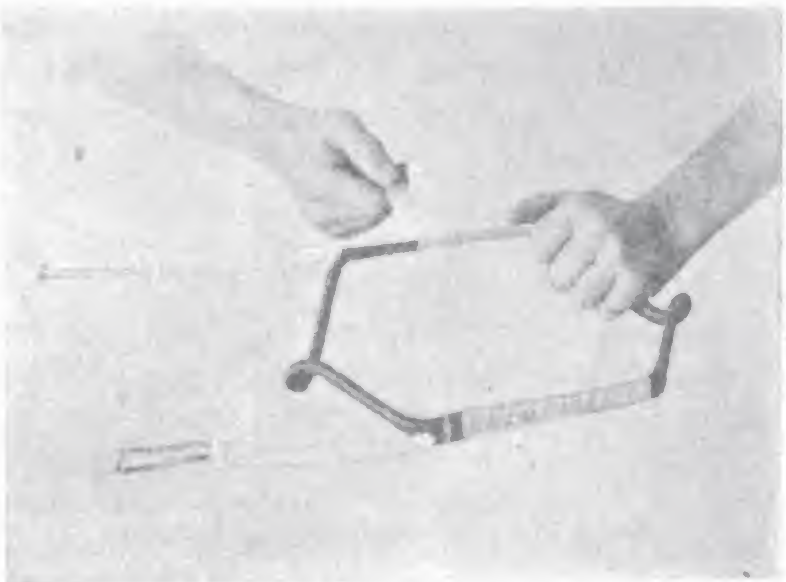


Figure 116.—Taping a coil by hand.

After the coils are placed in the armature slots you must connect their end leads to the commutator bars. If you remember your commutator construction you know that the leads are connected to the risers. A half-tin, half-lead solder is used plus a good soldering flux. Figure 117 shows the correct method.

The soldering iron is held vertically. Only the tip of the iron is used. This allows you to solder one bar at a time. Why the tilt to the armature? That's easy. It keeps the solder from flowing down the back of the commutator and causing short circuits.

Armature coils, even though placed in slots, might be thrown out when the armature rotates. Two methods are used to keep them in. Small armatures use a wooden wedge which is placed in the slot as shown in figure 118. Large armatures have bands of wire wound around the outer edges of the armature core. Figure 118 shows this band being applied to a large armature.

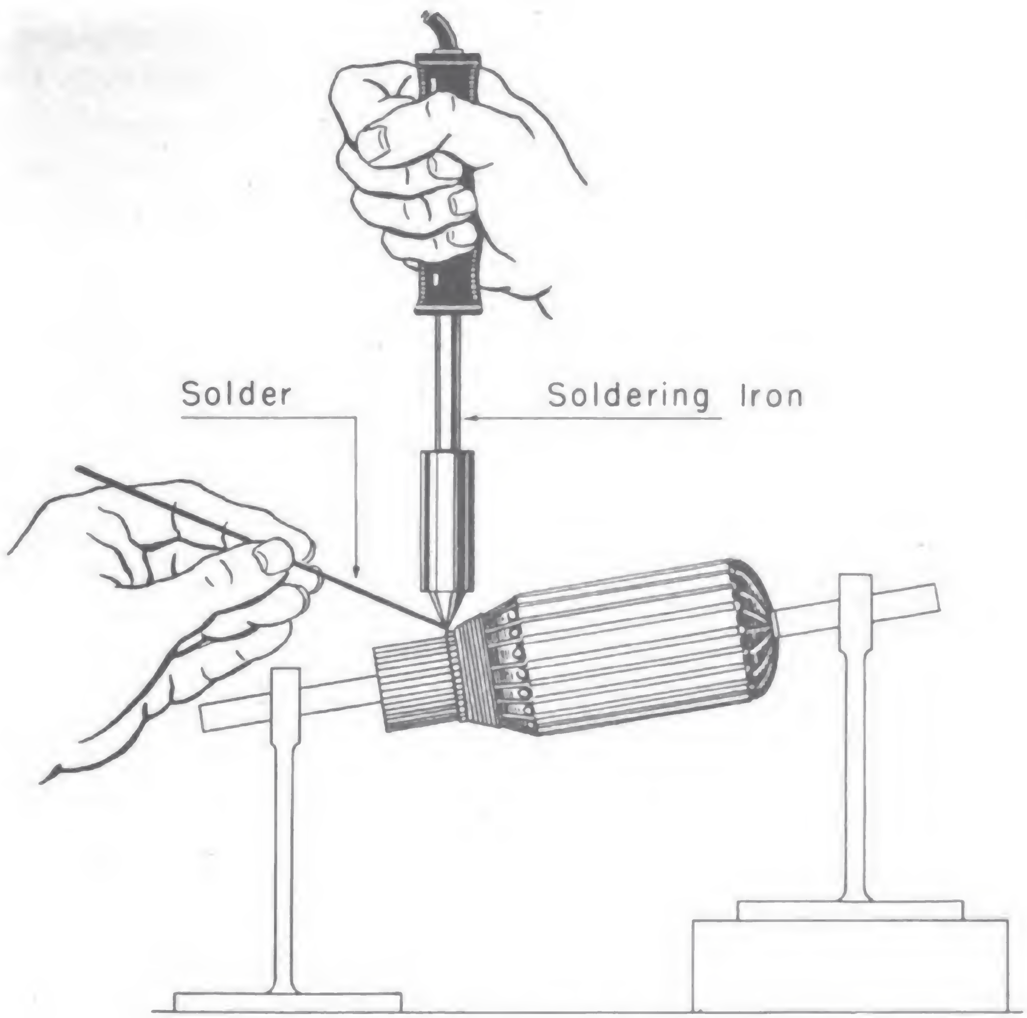


Figure 117.—Connecting coil leads to the commutator.

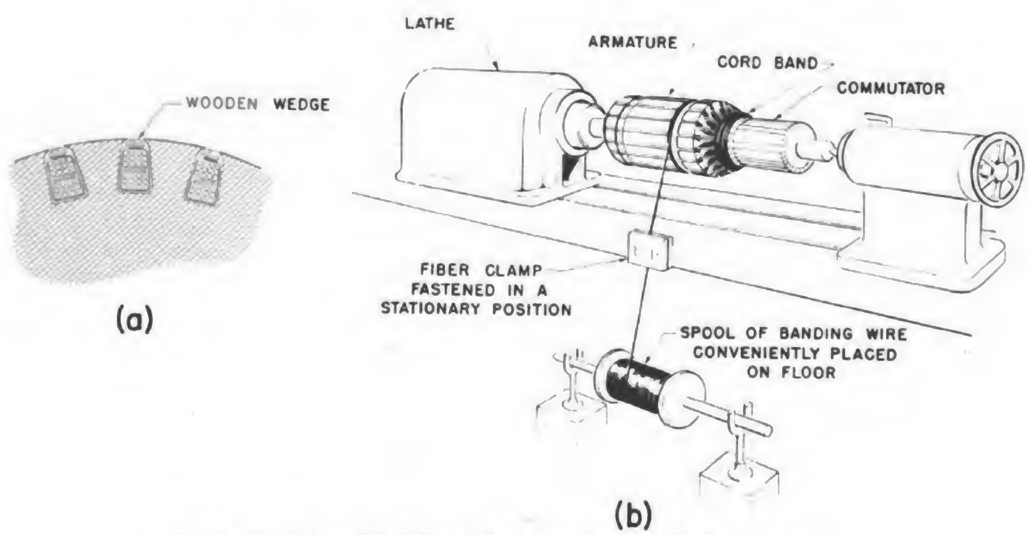


Figure 118.—Holding the armature coils in place.

Commutator leads also have a habit of flying out of place. Thus, on both large and small armatures a band or cord must be used to hold the commutator leads down. The bands are placed near the commutator end, of course. Take a close look at figure 117 and 118, and you'll see these commutator bands.

Varnishing and Baking

The last step in armature winding consists of varnishing and baking the whole armature. First, though, all moisture should be removed by placing the armature in an hot oven (250° F.). Keep it there for three hours.

Here's a point to remember. The varnish acts as an insulator. If it gets on the commutator you're headed for trouble. Tape should be applied to the commutator and shaft before dipping the armature into the varnish.

FIELD COIL WINDING

Field coils, of course, are either series, shunt, or compound wound. The series coil consists of a few turns of large-size wire. The shunt coil has many turns of small-size wire. The compound coil is made up of a series and a shunt coil. The exact number of turns used in the coil depends on the design of the machine.

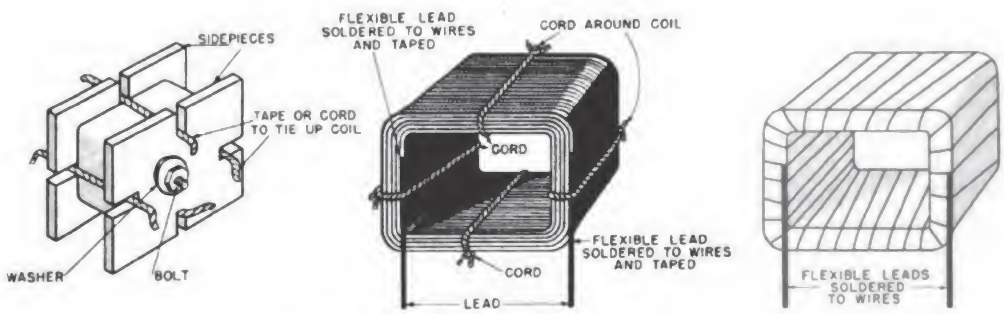


Figure 119.—Field coil winding.

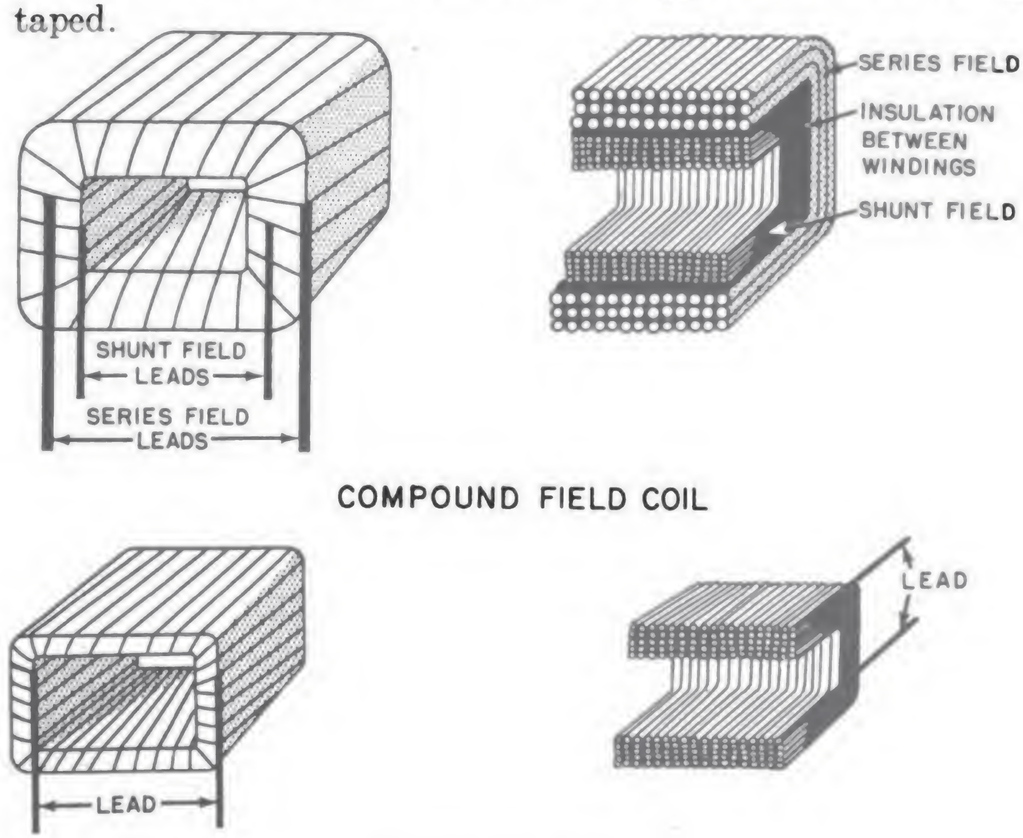
Field coils are first wound on a form to the size desired. Figure 119 shows you the construction of a typical wooden winding form.

After the required number of turns of wire have been made, the coil is removed from the form. Do you see those cords on

the wooden form? Here's where they come in. They are tied around the coil to hold the turns in place. You can see this in figure 119. Also notice the flexible leads which are soldered to the beginning and end of the coil.

The coil is insulated with cotton tape and varnished cambric. In some cases the coil is varnished and baked in a manner similar to the armature coils. The finished product is shown in figure 119. It is a series field coil.

A shunt field coil and compound field coil are shown in figure 120. Check their construction and appearance after being taped.



SHUNT FIELD COIL

Figure 120.—Construction of shunt and compound field coils.

ONE LAST WORD

Dismantling a motor or generator isn't child's play. Sure, it's true they have the same basic parts, but how they're put together is another matter. Motors and generators are designed to do certain jobs in certain places. That is the reason for the

different types of mechanical construction. For example, some machines have the end plates bolted directly to the yoke, in others they are connected together with through bolts. Some have the brush rigging bolted to the end frame, in others you'll find it riveted. Some have the pole pieces bolted to the yoke, in others the pole pieces and yoke are cast as one unit.

The point is this: Know your motor and generator construction before you start to tear it down. You can get this and other information from the manufacturer's instruction book which comes with each machine. Combine this information with the know-how of someone who has already worked on the machine, and you'll always do 4.0 work.

SUMMARY

A d. c. motor converts electrical energy to mechanical energy. Its output is rated in horsepower.

A d. c. generator converts mechanical energy to electrical energy. Its output is rated in watts.

A d. c. machine consists of these basic parts: Yoke or frame, end plates, pole pieces, field-coil windings, armature core, armature windings, commutator, and brushes.

A d. c. machine is designated by its internal connections between armature and field coils: series, shunt, and compound.

The commutator is the soft spot of the d. c. machine. It should be inspected frequently. Dirt should be removed with sandpaper—never with emery cloth.

Brush length should never be less than one-half of the original length. New brushes must be fitted to the commutator. Spring tension should be properly adjusted for best operation.

Bearings should be lubricated periodically. Overlubrication should be avoided.

Check the manufacturer's handbook before dismantling or lubricating a particular motor or generator.

Handle bearings gently. Wipe them with clean rags. Do not allow moisture to collect on bearing surface. Keep new bearings in their packages until ready to use.

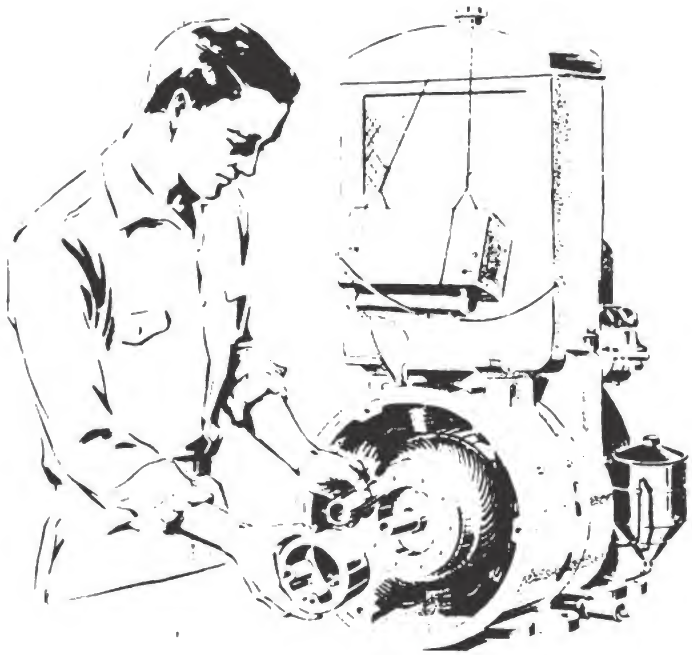
Armature coils are either lap or wave wound. Small armatures are hand wound. Large armatures use preformed coils.

A newly wound armature should be completely dried, dipped in varnish, and baked before using.

Field coils are preformed. They are insulated with cotton and varnished-cambric tape.

QUIZ

1. How are motors rated?
2. How are generators rated?
3. Into what two circuits can you divide the dynamo?
4. What two common types of bearings are used in motors and generators?
5. Name the parts found in the electrical circuit of a d. c. motor.
6. Why isn't the brush spring used to conduct the electricity from the brush to the brush holder?
7. Name three main classifications of d.c. motors.
8. What is the main advantage of a series motor?
9. What is the main disadvantage of a series motor?
10. What type of d.c. generator gives the best voltage regulation?
11. What are two "don'ts" to remember when cleaning commutators?
12. What is used to file the brush down so that it fits the commutator evenly?
13. What weight oil is generally used for lubricating motors and what is its Navy symbol number?
14. What is generally used to lubricate ball bearings?
15. What is generally used to clean the bearings?
16. Why is it necessary to apply tape to the commutator and shaft before dipping the armature in varnish?
17. Why is it important to keep new bearings in their packages until they are ready for use?
18. What publication may be utilized to great advantage when repairing motors and generators with which you are unfamiliar?



CHAPTER 5

ALTERNATING CURRENT GENERATORS

READ THIS FIRST

Are you familar with the basic facts of alternating current theory? Do you know the meaning of frequency, cycles, and phase difference? If the answer to either question is NO, then you have some reading to do. Where? Why, in your old buddy, *Electricity*, NavPers 10622, of course. Reading NavPers 10622 will pave the way to a better understanding of this chapter.

THE BASIC ALTERNATOR

One word for three? That's something you can't pass up. The word is ALTERNATOR. It's used to describe an ALTERNATING CURRENT GENERATOR.

There's a lot of argument about which came first, the alternator or the d.c. generator. That's as hard to answer as the chicken and the egg puzzle. There's one way you can keep out of hot water on this question. Just say the alternator and the d.c. generator were developed at the same time. You can use figure 121 to back up your claim.

Take a look at the d.c. generator, first. Essentially, it consists of a coil rotating in a magnetic field. The ends of the coil connect to a split ring which rotates with the coil. Each time a coil side moves past the north and south pole, the current induced in the coil will REVERSE its direction. It's the same old story: a rotating coil in a magnetic field produces ALTERNATING VOLTAGE.

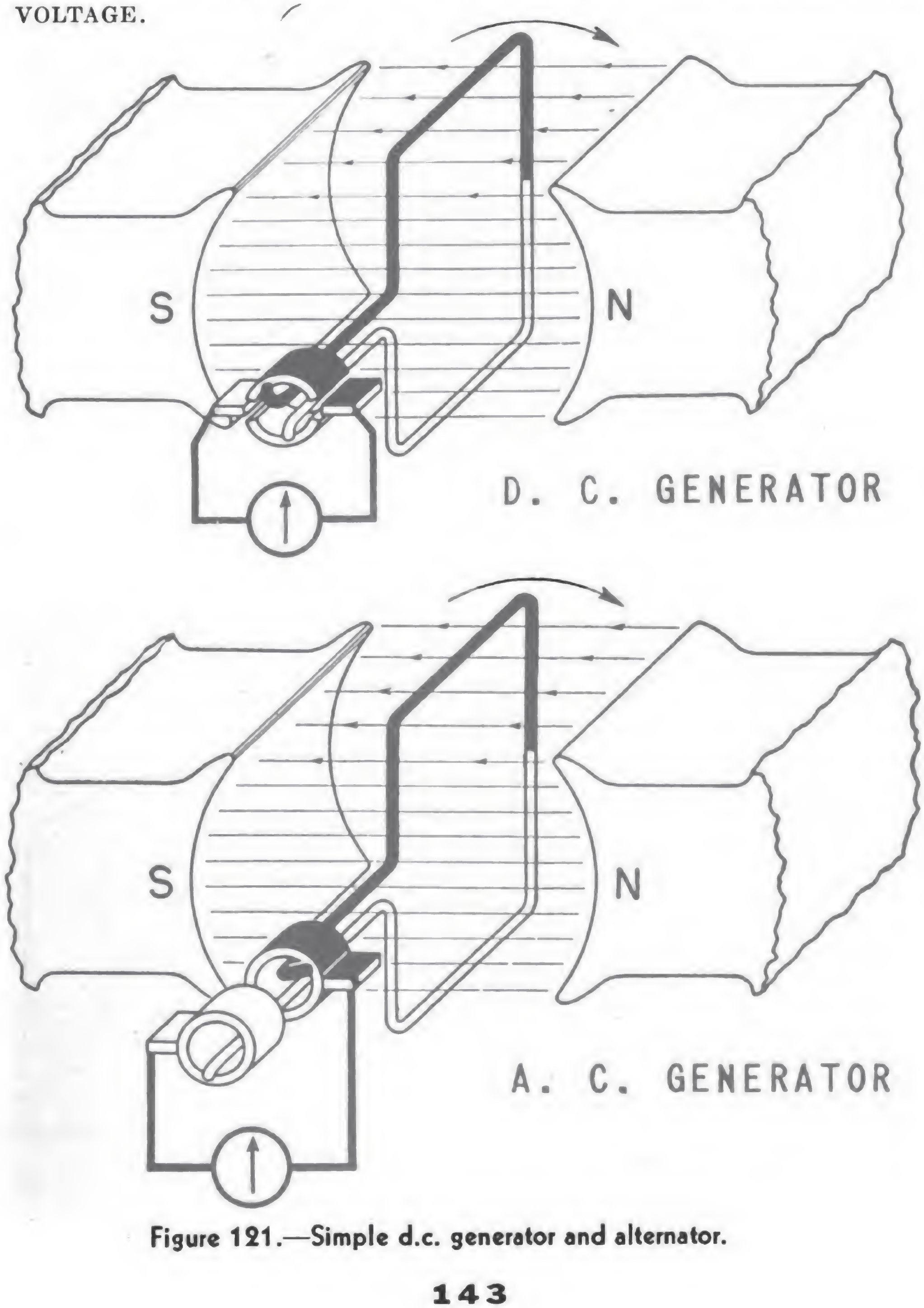


Figure 121.—Simple d.c. generator and alternator.

That takes care of the alternating part of the generator, but what about direct current end? You know the answer. It's the split rings or COMMUTATOR that changes the alternating current to direct current. Thus, a D.C. GENERATOR IS ACTUALLY A SIMPLE ALTERNATOR WITH A COMMUTATOR.

Changing the d.c. generator to a complete alternator is an easy step. All you have to do is substitute a CONTINUOUS band of copper or SLIP RING for each section of the commutator. You end up with two slip rings, each connected to a coil end. Brushes riding on these rings pick off the alternating current generated in the coil and deliver it to the external circuit.

ALTERNATORS vs. D.C. GENERATORS

Why is it necessary to have both alternators and d.c. generators? A good question and a simple one to answer. It's as

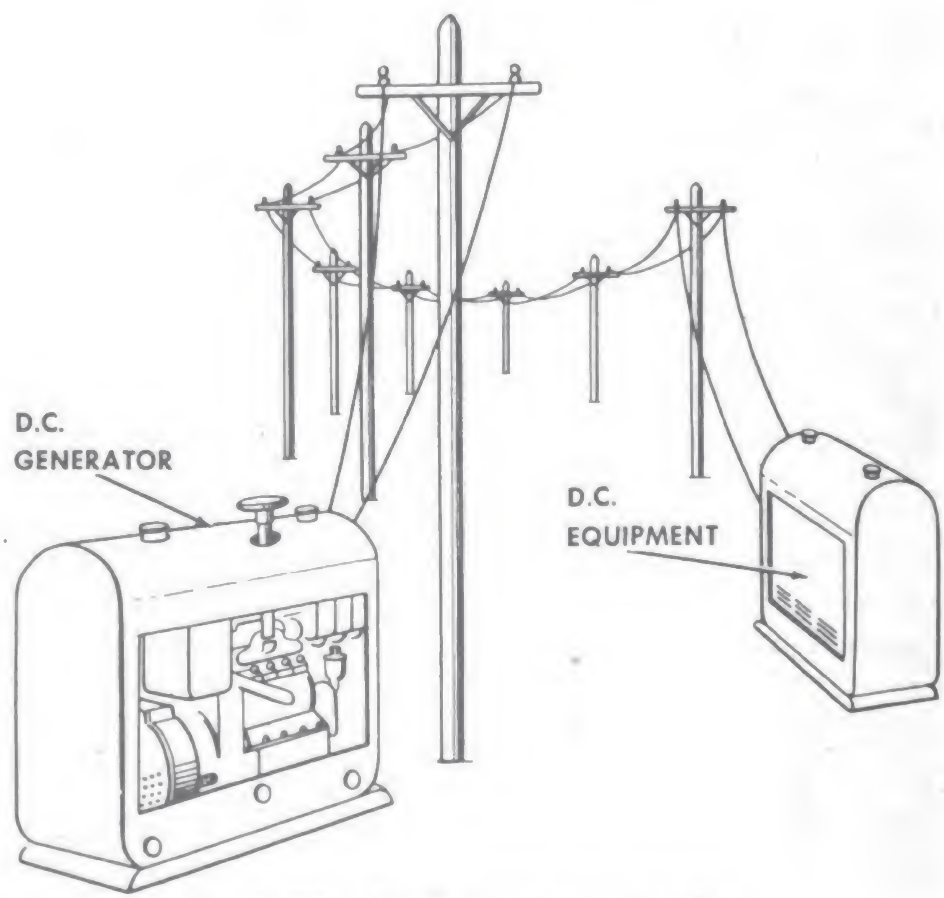


Figure 122.—Direct current power transfer.

easy as this: alternating current has certain advantages that direct current doesn't possess. One of these advantages is the ability to transfer power for long distances.

Take a look at figure 122. It shows a d.c. generator feeding power to d.c. equipment. A distance of 1 mile separates the generator and the equipment. The wires which carry the direct current over to the equipment have a definite resistance. The longer the wire, the greater the resistance. In this case the total wire resistance is 1 ohm.

The generator has an output of 230 volts. Forty amperes of current flow through the wires. The equipment needs at least 220 volts for efficient operation. A check at the equipment end, however, shows a voltage of only 190 volts. That indicates a loss of 40 volts between generator and equipment.

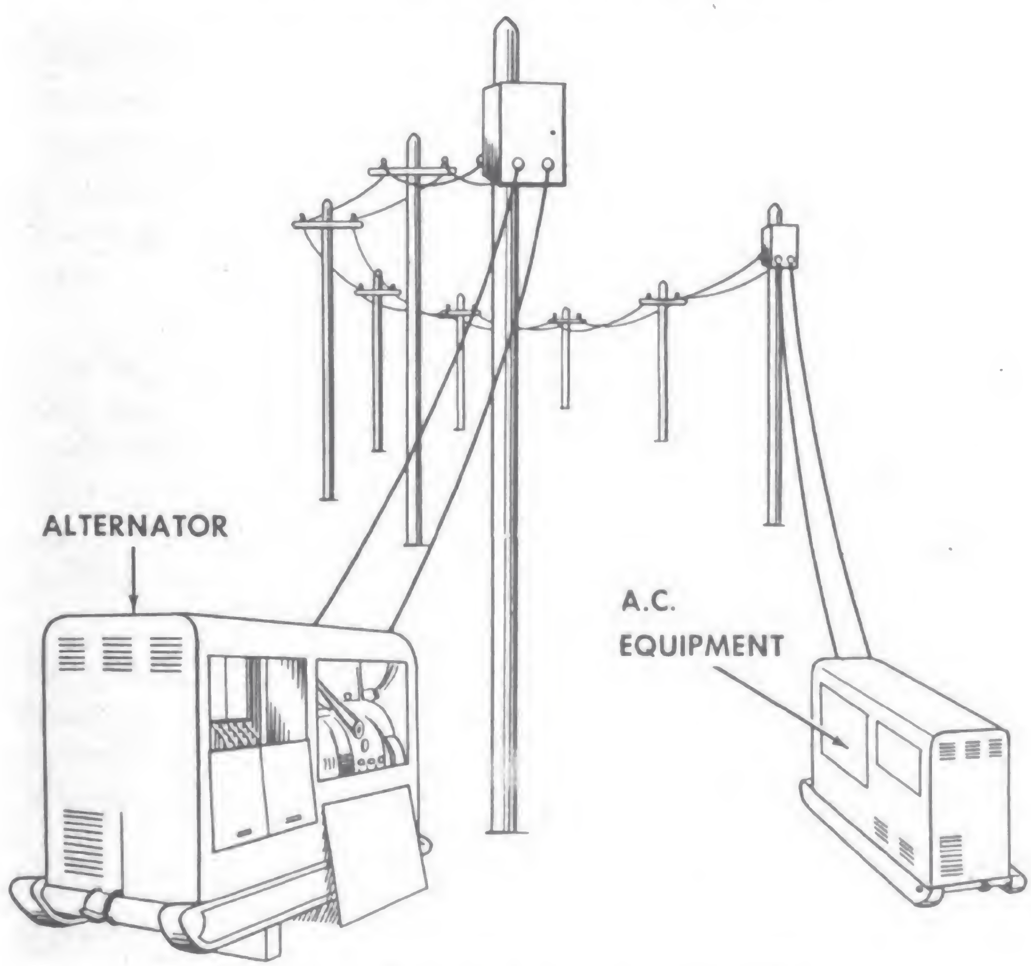


Figure 123.—Alternating current power transfer.

You know how the 40 volts are being wasted. It's the result of 40 amperes of line current bucking 1 ohm of line resistance. Now, you could increase the generator voltage by increasing the size of the generator, but that leads to construction difficulties. You might also decrease the wire resistance by increasing the wire size. But that requires a heavier wire which not only costs more, but is harder to handle. There's an easier way. Use an alternator.

Figure 123 shows you the alternating current set-up. The d.c. generator has been replaced with an alternator, the d.c. equipment with a.c. equipment. You still have 1 mile of wire separating the generator and equipment. The big difference, however, is the two TRANSFORMERS—one inserted at the generator end and the other at the equipment end.

You've read *Electricity*, NavPers 10622, so you know the basic facts of transformer theory and operation. You've learned that the transformer is used to STEP UP (increase) a.c. voltage. It is also used to STEP DOWN (decrease) a.c. voltage. At the same time that a transformer steps up the voltage it DECREASES the current. A step-down in voltage is accompanied by an INCREASE in current. An inverse ratio exists between voltage and current change.

Now, to get back to figure 123. The alternator has an output equal to 230 volts and 40 amperes—the same as the d.c. generator shown in figure 122. The transformer at the alternator end steps up the 230 volts to 2,300 volts on the line. This is a step-up ratio of 1 to 10. The current, therefore, decreases from 40 amperes to 4 amperes—a step-down ratio of 10 to 1.

Four amperes of current is now flowing in that 1 mile of wire. Four amperes bucking 1 ohm of resistance means a waste of only 4 volts. Four volts subtracted from 2,300 volts leaves 2,296 volts at the equipment end. The transformer at the equipment ends steps this down to 229.6 volts.

Thus, from generator to equipment there is a loss of .4 volt. That's quite different from the 40-volt loss when the direct current generator was used. Of course, it's the transformers that did the trick. Why weren't the transformers used in the

d.c. circuit? You probably know the answer. TRANSFORMERS CAN'T BE USED TO INCREASE OR DECREASE D. C. VOLTAGE

Construction

Some of the small alternators you'll work with will be constructed like the d.c. generator. That is, they will have REVOLVING ARMATURE COILS and STATIONARY FIELD COILS. Of course, slip rings are substituted for the commutator.

The larger alternators have a different set-up. Take the small alternator, turn it inside out, and you've got the basic construction of the large alternator. The armature coils are placed in the stationary frame termed the STATOR. The field-coil windings are placed on the rotating shaft, termed the ROTOR. Figure 124 shows you the basic difference between small and large alternators.

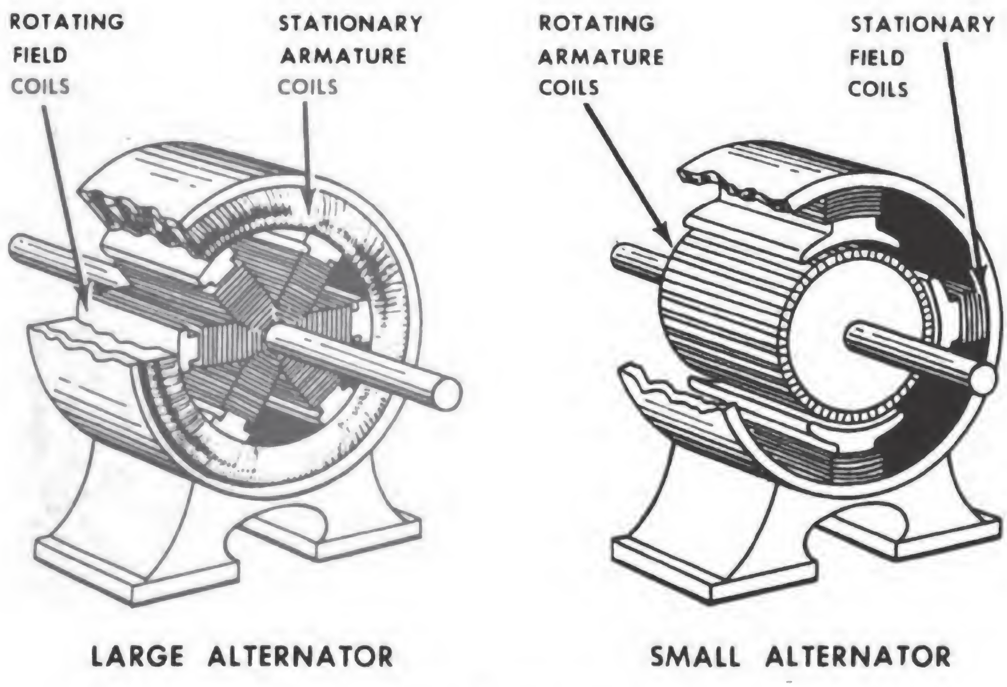


Figure 124.—Basic difference between small and large alternators.

There's a definite advantage in thus using the stator and rotor. Since the voltage is generated in stationary coils, it may be transferred DIRECTLY to the external circuit. That means the elimination of slip rings and brushes in the stator circuit. Higher

voltages may be generated and insulation becomes no problem at all.

Of course, you can't get completely away from slip rings and brushes. The field-coil windings must be fed with direct current as they rotate. No direct connection between field windings and d.c. source is possible. Therefore, slip rings and brushes must be used as a sliding contact.

The maintenance on the slip rings and brushes is a "snap." That's because only a low d.c. voltage is needed to excite the field windings. A low voltage on the brush and slip ring allows little chance for sparking. Thus, your maintenance of slip ring surface is reduced.

Operation

How can the alternator generate an e.m.f. if the armature coils are held stationary and the field coils rotate? Figure 125 shows you the principle. In view *A*, a conductor is moving through a stationary magnetic field. As the conductor cuts the lines of force an e.m.f. is induced in the conductor. If you were sitting

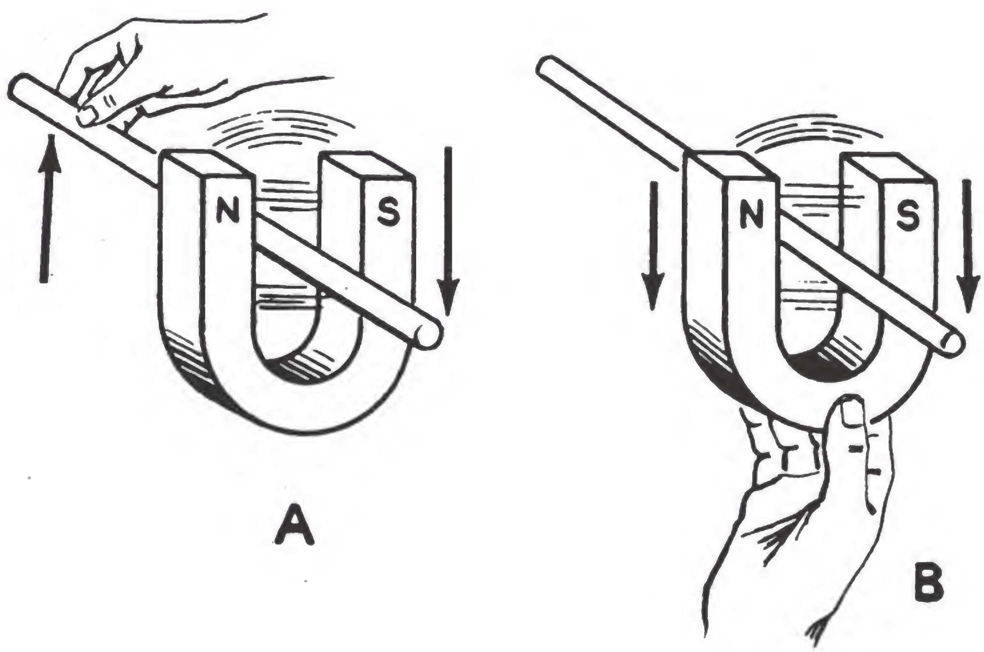


Figure 125.—Generating an e.m.f.

on that conductor as it moved, you would see the magnetic lines go slipping by.

Now look at view *B* of figure 125. In this case the conductor is held stationary and the magnet is moved. As the magnet moves, the magnetic field moves with it. The lines of force will cut the stationary conductor and induce an e.m.f. in it. If you were sitting on the stationary conductor, you would still see the magnetic lines move by. Thus, it doesn't matter which moves, the magnetic field or the conductor. All that's required is a relative motion between the two.

It's just a step from the moving field and stationary wire of figure 125 to the 4-pole alternator of figure 126. The construction of the windings is a little more complicated but the principle is the same.

The field coils produce a magnetic field when direct current flows through the windings. This magnetic field ROTATES with the field coils. As it rotates, the magnetic lines of force sweep across the STATIONARY armature coils inducing an alternating e.m.f. The alternating e.m.f. is brought out to the external circuit by means of direct connected leads.

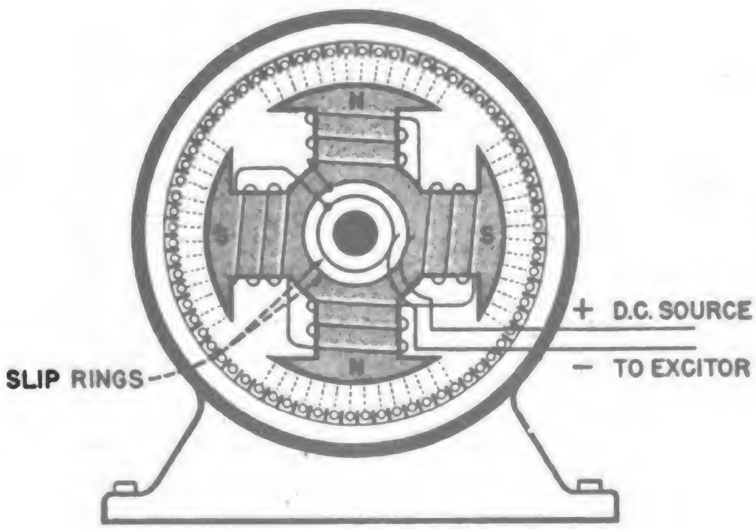


Figure 126.—Four-pole alternator.

The fact that alternators have stationary coils should hold no fears for you. Coils are placed in the stationary frame only for convenience of design. You'll find that the winding principles still hold true. The span of each coil will still be equal to the distance between alternate north and south poles. Thus, when one coil side is under a north pole of the rotating field poles, the other coil side will be under a south pole.

SINGLE-PHASE AND THREE-PHASE ALTERNATORS

A simplified diagram of a SINGLE-PHASE alternator is shown in figure 127. Notice that there is only ONE WINDING placed on the stator. The voltage produced by this alternator is just a SINGLE alternating e.m.f. If you could see this voltage it would resemble the wave form shown in figure 128.

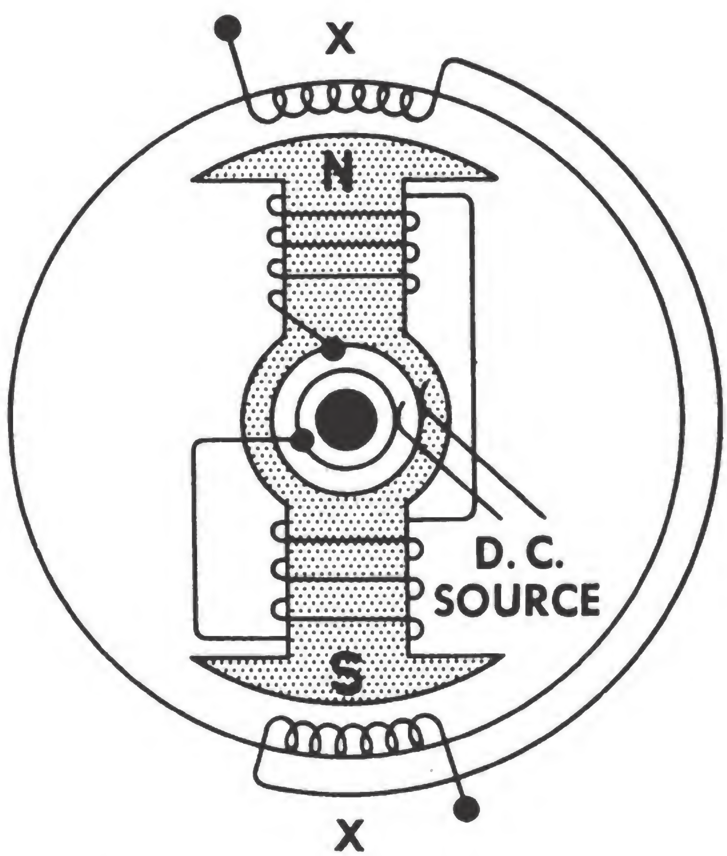


Figure 127.—Single-phase alternator.

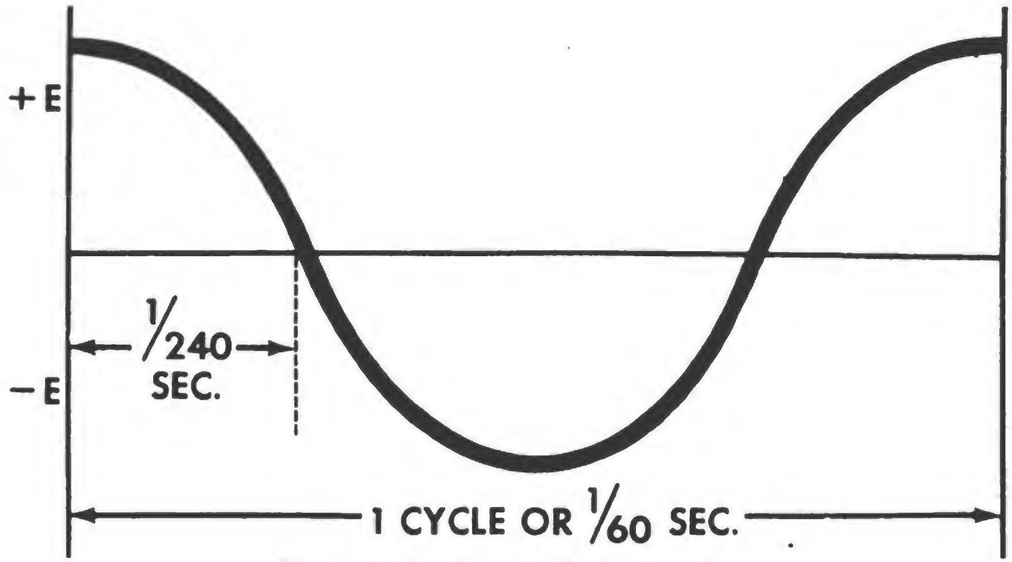


Figure 128.—Single-phase voltage.

Take a single-phase alternator, add two more separate windings, and you have a THREE-PHASE ALTERNATOR as shown in figure 129. It is three single-phase alternators rolled into one. The revolving field poles induce an alternating e.m.f. in each set of coils. Thus, therewill be three voltage wave forms impressed on the line.

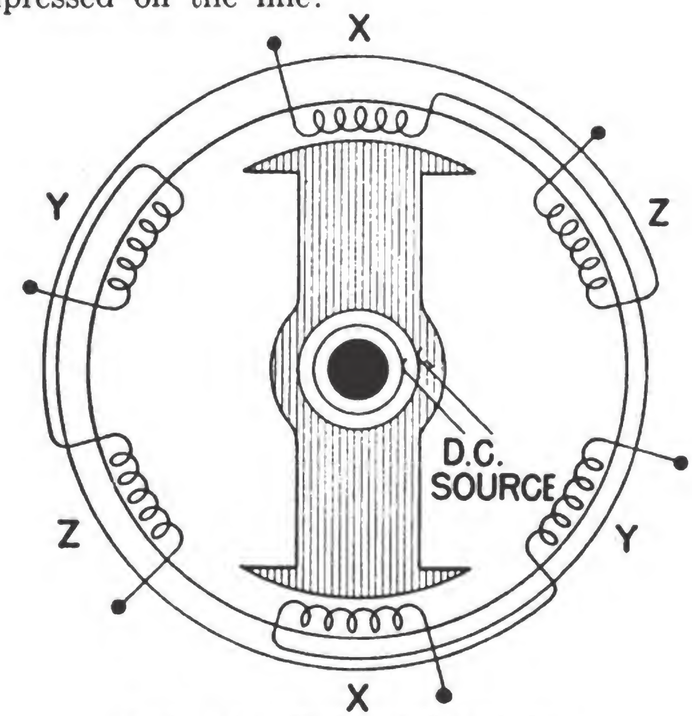


Figure 129.—Three-phase altemator.

Figure 130 shows you the appearance of a three-phase voltage wave form. The phase difference between each voltage is 120 electrical degrees. That's because each winding is spaced 120 degrees apart on the stator.

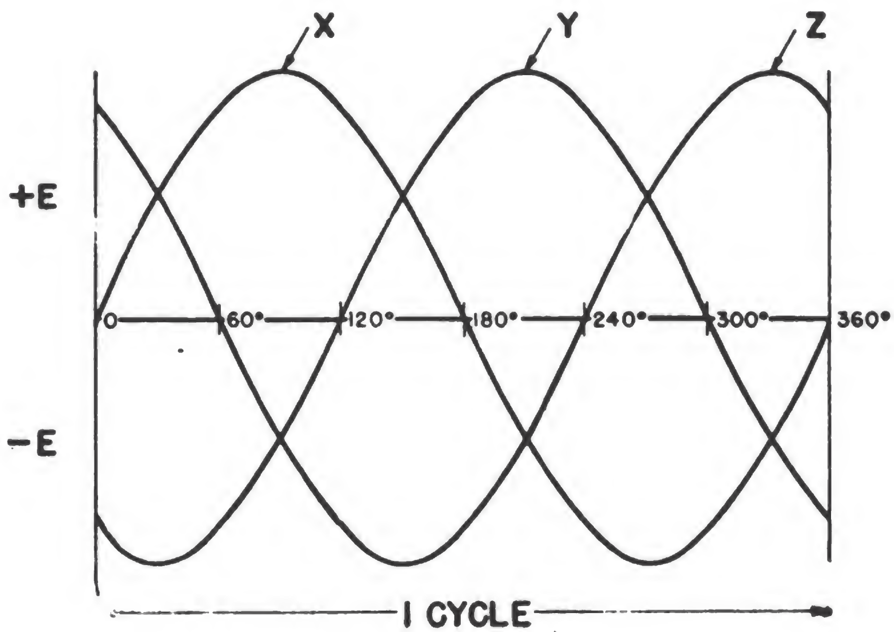


Figure 130.—Three-phase voltage.

Three-phase alternators are the big jobs. They are used where the power demand is greatest and where a.c. motors and lights are run off the same circuit. Small portable alternators are usually of the single-phase type. Their greatest use is in the emergency powering of small lighting systems.

THE EXCITER

Direct current generators and alternators go together like ham and eggs. That's because direct current is needed to energize or excite the field coil windings of the alternator. The d.c. generators used for this purpose are termed EXCITERS. They are usually the shunt-field type.

Both the exciter and alternator convert mechanical energy into electrical energy. The mechanical energy is produced by either a gas or Diesel engine, known as a PRIME MOVER.

Figure 131 shows you how the exciter and alternator team up to do the job. Mechanical energy forces the armature of the exciter to rotate. Electrical energy is removed from the commutator in direct current form. This energy is fed into the field coils of the alternator. Mechanical energy forces the field coils of the alternator to rotate. Electrical energy is removed from the stator coils in the form of an alternating e.m.f. It is this energy which powers the motors and lights.

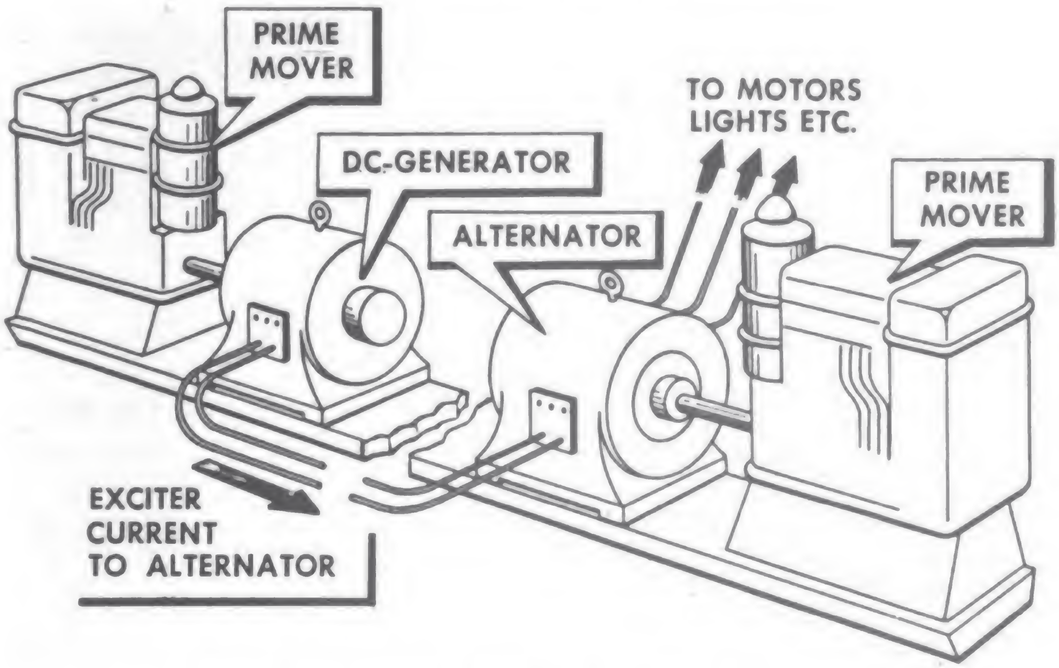


Figure 131.—Exciter and alternator operation.

Check figure 131 and you'll find two prime movers, one for the exciter and one for the alternator. Each of the prime movers produced the same thing—mechanical energy. So why not combine the two? It would mean less maintenance and fewer units to move around.

Using one prime mover for both the exciter and alternator is as easy as adding one and one. All you have to do is place the exciter on the same shaft as the alternator. The prime mover will turn the field coils of the alternator. At the same time it will rotate the armature of the exciter. Figure 132 shows you an alternator with the exciter mounted on the end. This type of exciter is termed a DIRECT-CONNECTED EXCITER.

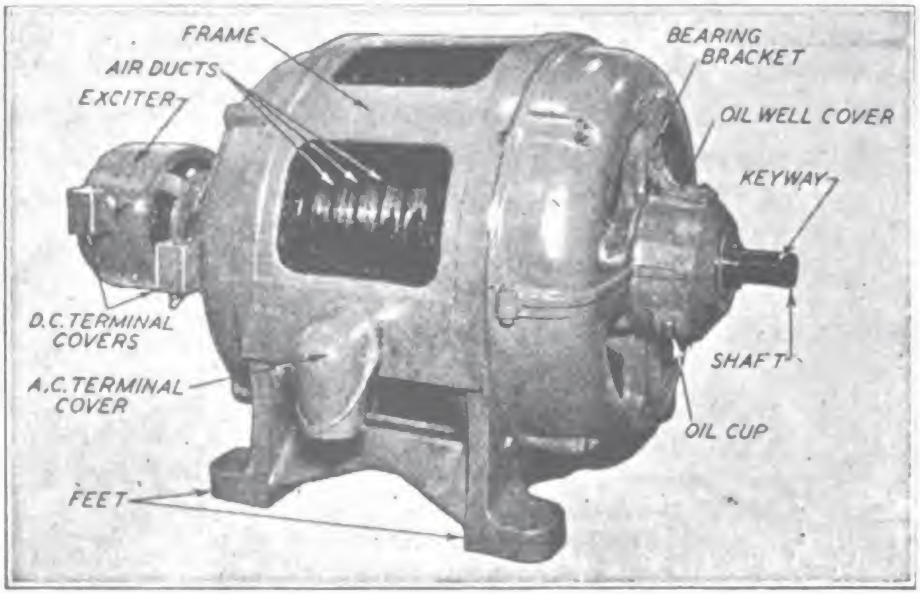


Figure 132.—Direct-connected exciter.

MECHANICAL CONSTRUCTION

You're familiar with the mechanical construction of the d.c. generator. That puts you one step ahead when it comes to learning about the construction of the alternator. You'll find that the alternator and d.c. generator have the same basic parts.

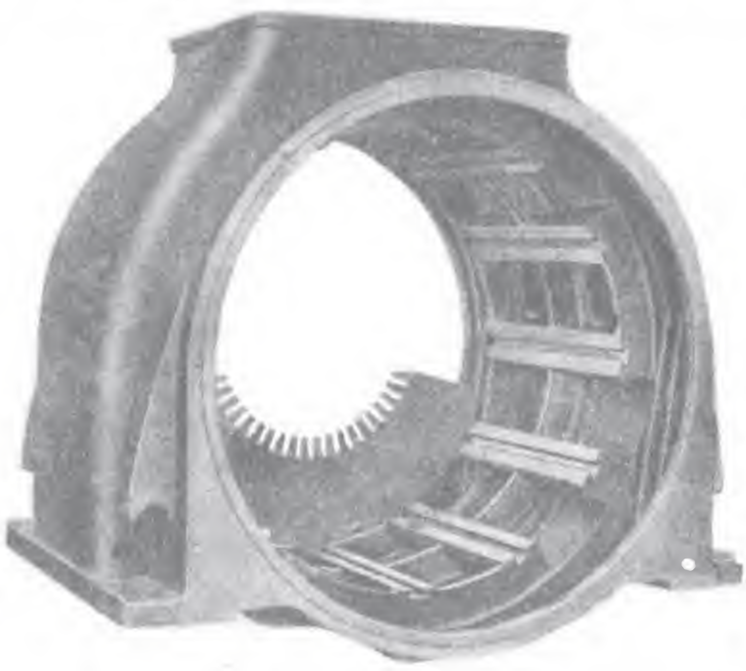


Figure 133.—Alternator frame and stator core.

For example, there's a FRAME or YOKE. It holds the stator core in which the stator coils are mounted. It also acts as the support for the end plates.

The STATOR CORE is made up of thin sheets of stamped metal. Each sheet of metal is mounted and bolted on the inside diameter of the frame. This forms a LAMINATED STATOR CORE. Figure 133 shows an alternator frame. One sheet of the stator core is shown in position. Notice the slots into which the stator coils fit.

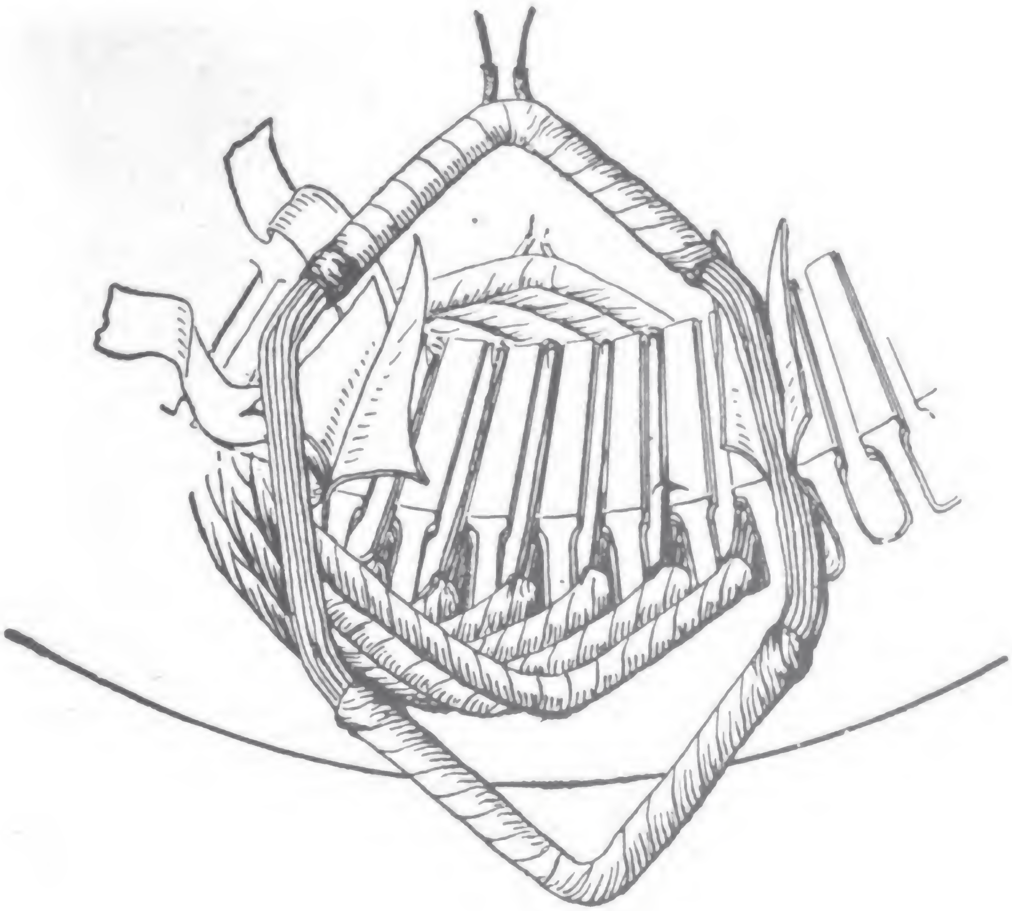


Figure 134.—Stator coils inserted in stator slots.

The STATOR COILS are preformed just like those used in large d.c. armatures. After forming, the coils are taped and baked for insulation purposes. Figure 134 shows you a section of the stator core with the coils being inserted in the slots.

The rotor of the alternator consists of the REVOLVING FIELD ASSEMBLY. Like the d.c. generator, the coil windings fit over

a POLE CORE. The pole cores are either dovetailed or bolted to the rotor. A dovetailed rotor assembly is shown in figure 135. This assembly is pressed onto the shaft of the prime mover.

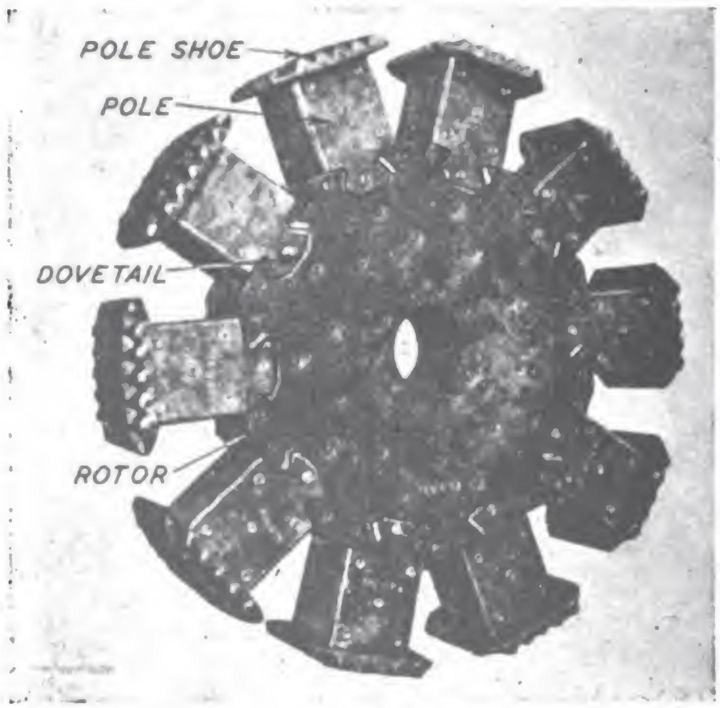


Figure 135.—Rotor with dovetailed pole piece.

The poles in figure 135 are empty. You know, of course, that FIELD WINDINGS fit over these pole pieces. Figure 136 shows you a pole piece with the field winding in place.

Figure 136.—Field coil and pole piece.

Now take a look at figure 137. It shows the completed field coils mounted on the rotor. Notice that in this case they are bolted to the rotor.

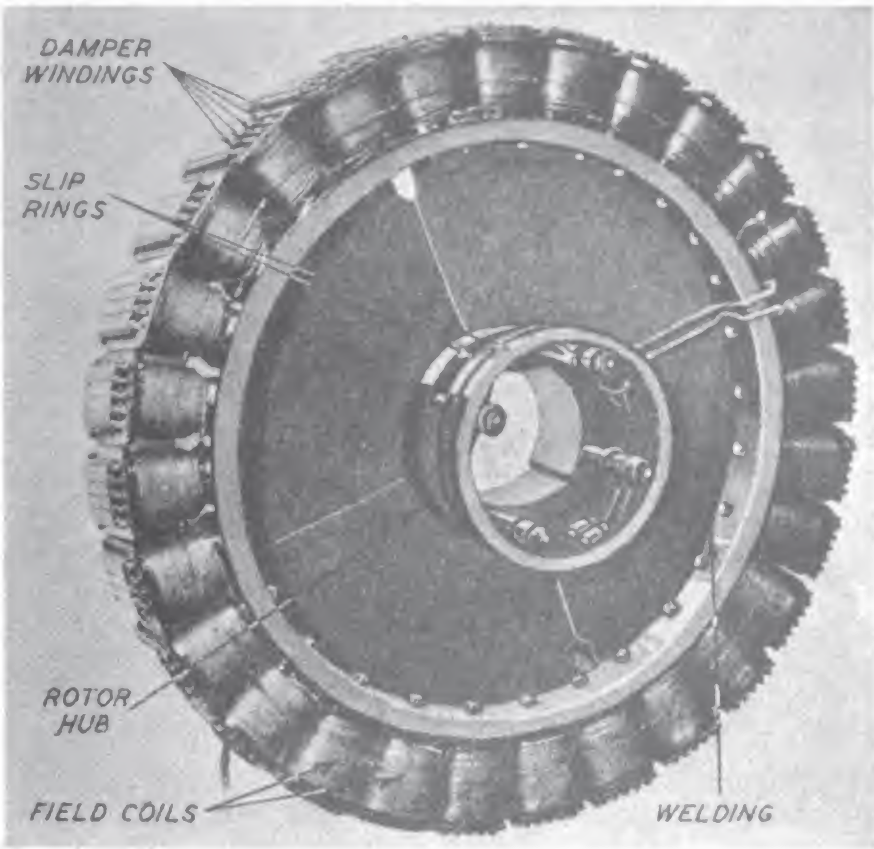


Figure 137.—A complete rotor.

What you can't see in figure 137 are the connections between each field coil. They are connected in series. Check figure 137 closely and you'll see two leads coming from the field coils down to the slip rings. These leads bring the exciter current into the field windings. The slip rings, of course, are insulated from rotor and shaft.

Put the rotor and stator together and you have a complete alternator as shown in figure 138. This happens to be an alternator which uses a Diesel engine as a prime mover.

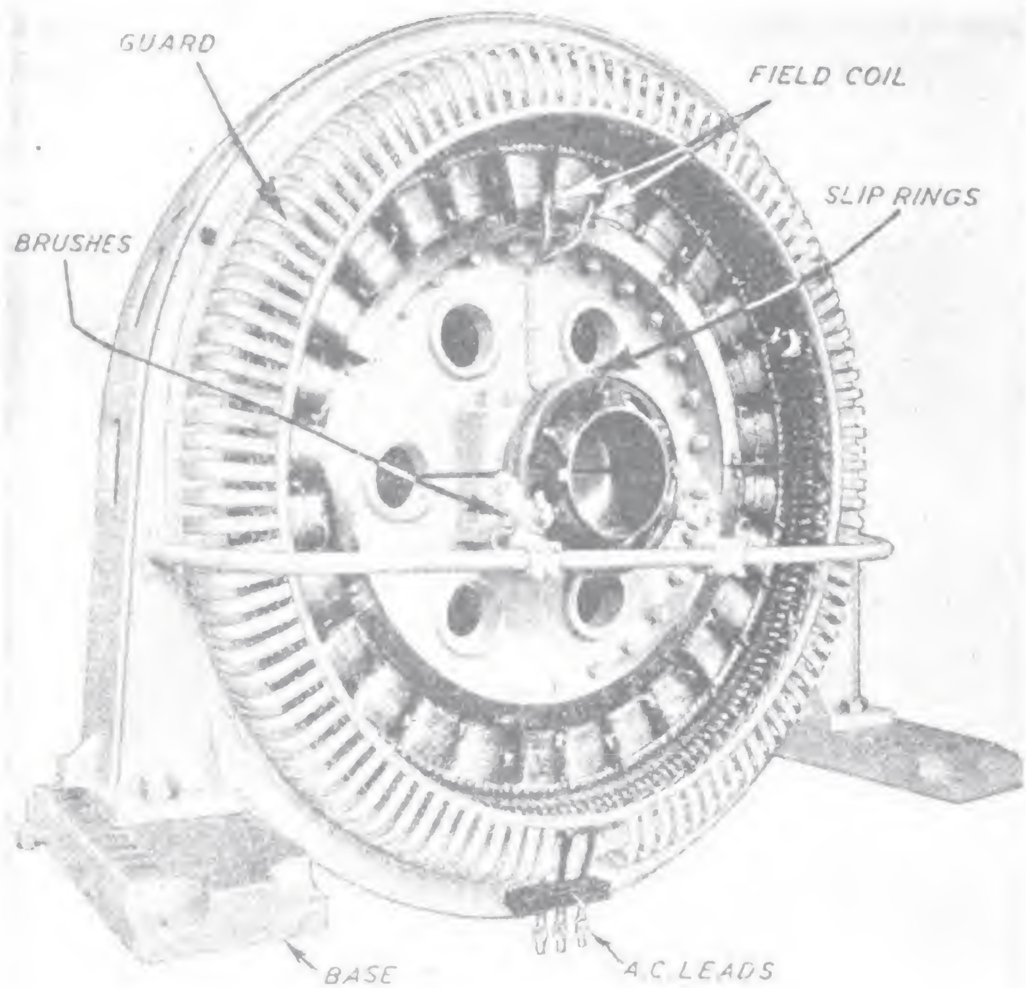


Figure 138.—Complete alternator.

DISMANTLING THE ALTERNATOR

You're going to run across many different types of alternators. They will all have the same basic parts. How they are put together, though, is another story.

It stands to reason that one alternator can't be built to fit every job. Some are small for portable, light work. Others are large for stationary, heavy-duty work. Some are constructed to withstand the punishment of weather in outside locations. Others are designed for work in protected spots.

All this doesn't mean that you should tear an alternator down in a hit and miss fashion. Each alternator unit is accompanied

by a MANUFACTURER'S INSTRUCTION BOOK. In it you'll find all the information you need for dismantling and putting together the alternator you are working on.

Just how is all this accomplished? Well, take a look at figure 139. It shows the exploded view of the alternator and exciter used in a gas-engine-driven alternator. It was taken from the instruction book for that particular unit. Can you ask for a more simple and helpful explanation of the alternator's construction?

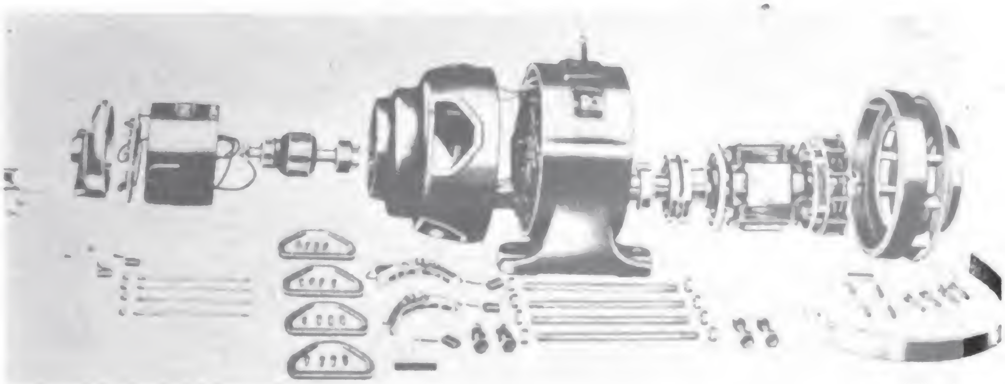


Figure 139.—Exploded view of alternator and exciter.

Of course, the exploded view gives an over-all picture of what you will get into. You'll find detailed explanations of disassembly in the instruction book, also. For example, if you wanted to know the procedure to follow in removing the exciter brush ring, you would look at figure 140. With the detailed written explanation, the job is made easy.

Removing the field assembly from the engine crankshaft is also an easy process, if you use the instruction book. Figure 141 shows you the method. You can see how the long Allen wrench is used to remove the screws in the shaft clamp. Precautions are also listed for this particular job. For example, you are warned to wrap all bearings in a paper or rag to protect them against dirt.

Remember that every alternator you work on is an important link in some electrical system. Its care and maintenance has been entrusted to YOU. Use your common sense and the manufacturer's instruction book, and you can't go wrong.

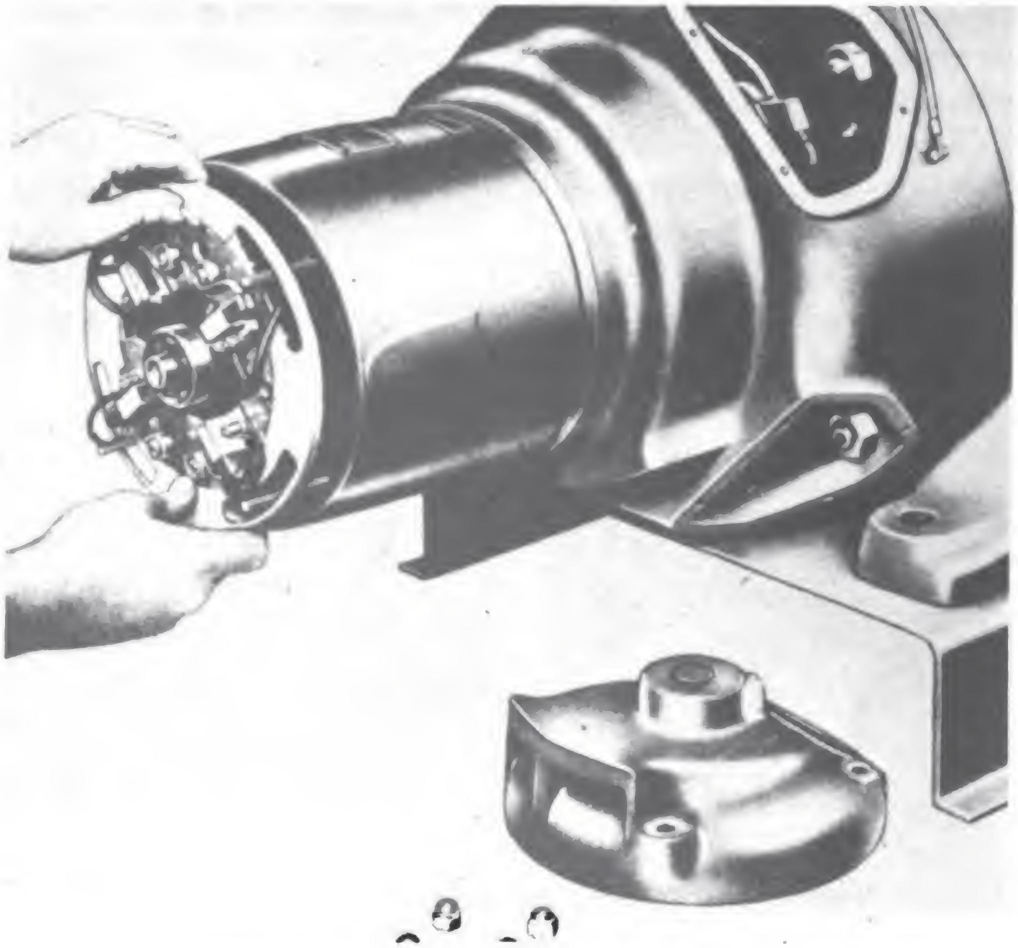


Figure 140.—Removing the exciter brush ring.

SIMPLE REPAIR AND MAINTENANCE

Brushes, bearings, commutator, slip rings—do these names sound familiar? They should, because except for the slip rings, you've read all about their maintenance in the chapter on d.c. generators. Sure, they're in the alternator now, but that doesn't change the part each plays.

BRUSHES are still used to conduct current from rotating circuit to stationary circuit. In this case you'll find them riding not only on the commutator of the exciter but on the slip rings of the rotor. You'll have to make periodic checks on their lengths and replace them when they are worn down. You'll have to fit new brushes to the contour of the commutator and slip rings and check for proper spring tension.

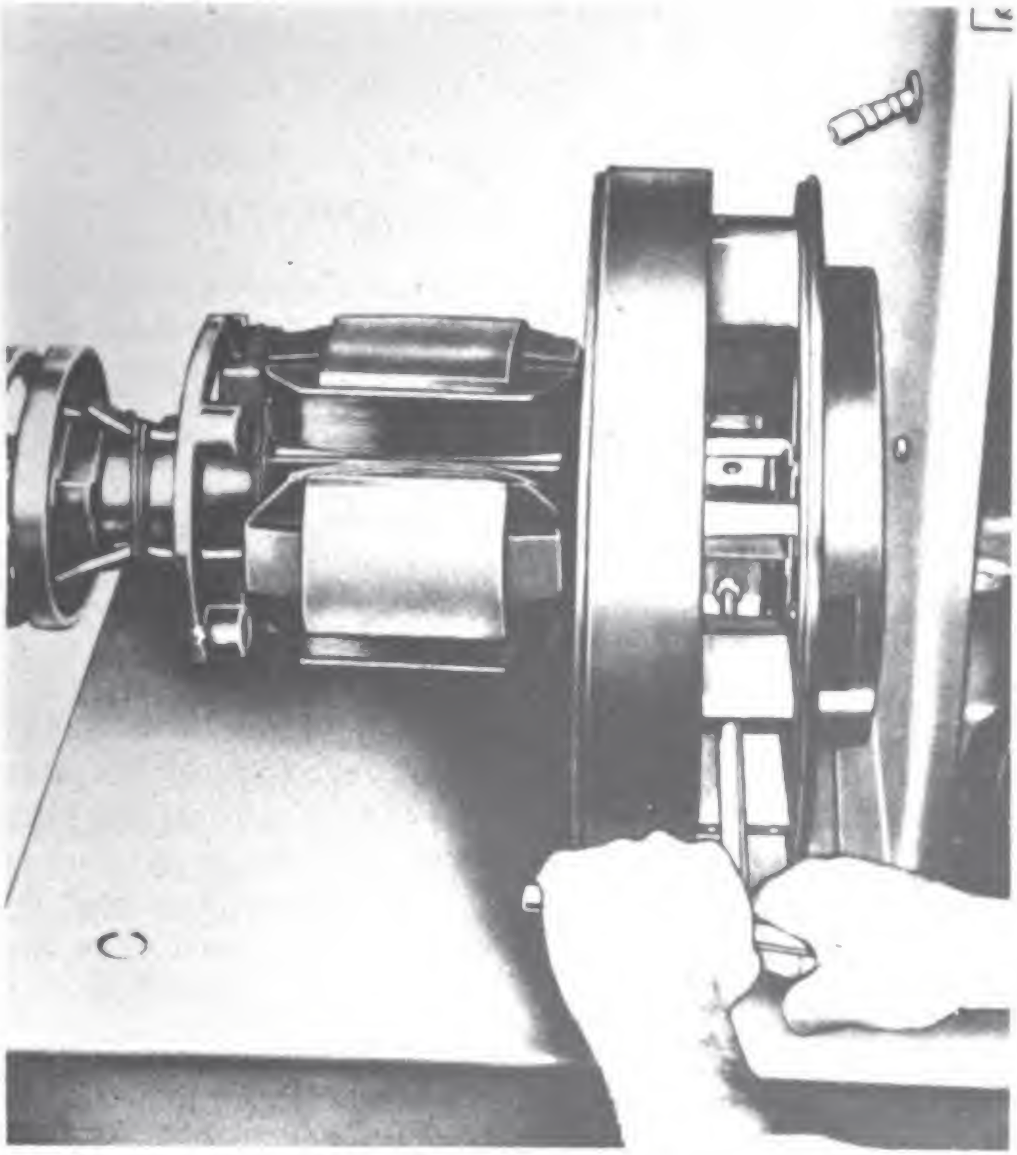


Figure 141.—Loosening the shaft-clamp screws.

BEARINGS on alternators are no different than those on d.c. generators. They're used to reduce the friction of the rotating shaft. Your job will be to maintain proper lubrication and replace them when necessary.

COMMUTATORS on exciters still get as dirty as those on d.c. generators. They will need constant attention and cleaning. You have the know-how on tools and methods.

SLIP RING maintenance shouldn't cause you any trouble. Give them the same care as the commutator and you can't go wrong.

Keeping the alternator in good mechanical condition will pay off in big dividends. A regular schedule of cleaning and inspection should be followed.

CONTROLLING THE ALTERNATOR

An alternator is just PART of the electrical system. Sure, it produces the electrical energy but don't give it all the credit. Remember those a.c. motors on the other end of the line? Without them you couldn't convert that electrical energy into useful work.

The motors will do their share, if the alternator does its job. That job is producing correct A.C. FREQUENCY and VOLTAGE OUTPUT.

Frequency Output

Alternator frequency depends on two things: the NUMBER OF POLES in the rotating field, and the SPEED at which the poles rotate. Every time a pair of poles goes by a coil side you have a reversal of current. If you increase the number of pairs of poles you naturally would increase the number of current reversals in a given time. The same effect is obtained when you increase the speed of the rotating field poles.

You can't change the number of poles. That was determined when the alternator was built. You can change the speed, however. The rotating field poles are mounted on the shaft of the prime mover. Changing the speed of the prime mover will directly affect the frequency output of the alternator.

The prime mover is either a gas or Diesel engine. If you've ever driven an automobile you know how the engine speed is changed. It's just a matter of stepping on the accelerator. This controls the amount of fuel introduced into the cylinders. The more fuel, the greater the speed.

In the prime mover the same principle holds. In this case, however, a hand THROTTLE is used instead of a foot control. By adjusting the throttle you can bring the alternator up to its correct speed. In most cases the alternator frequency is set for 60 cycles.

Voltage Output

When the rotating magnetic field sweeps across the stator coils it induces an e.m.f. in the coils. If the speed is constant, the value of this e.m.f. will depend on two things: the number of magnetic lines of force in the field, and the number of turns of wire in each stator coil. The number of turns of wire is fixed at the factory—so you can't change that. The number of magnetic lines of force in the field can be changed.

After all, the field coils of the alternator are nothing more than electromagnets. The strength of its magnetic field is directly controlled by the amount of current flowing through its turns of wire. The greater the current, the greater the field strength. Therefore, if you wanted to reduce the field strength of the alternator you would reduce the amount of exciter current. If you wanted to increase the field strength, you would increase the amount of exciter current.

The exciter current is the result of the exciter voltage impressed across the resistance of the rotating coils of the alternator. It's just a simple application of Ohm's law. To change the exciter current you change the exciter voltage.

Now, how can you control the exciter voltage? Well, where does the exciter voltage come from? You should know the answer to that. It's the result of the rotation of the armature coils of the exciter in the magnetic field. The stronger the field the greater the exciter voltage produced.

Varying the exciter's field strength is easy. All you have to do is insert a variable resistance in SERIES with the shunt-field windings. Increasing or decreasing the resistance will control the exciters output voltage which is fed to the alternator.

Figure 142 shows you the front and back view of a typical variable resistor. It is called a RHEOSTAT. To conserve space the resistance element is mounted on a circular form. Notice that handle. It is attached to a sliding contact which rests on the resistance element. Turning the handle moves the contact which changes the amount of resistance in the exciter field.

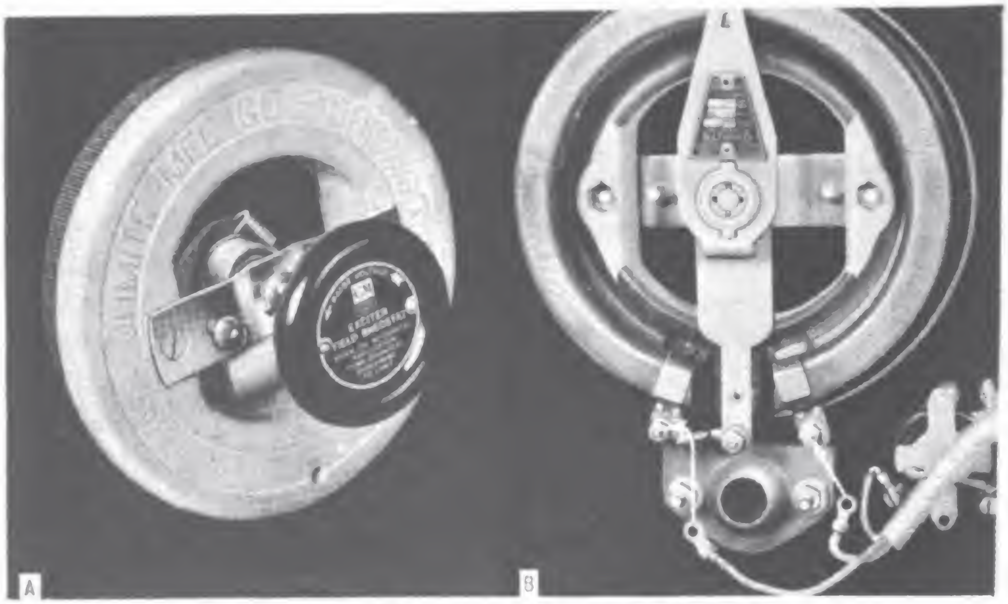


Figure 142.—A typical exciter field rheostat.

To get a clearer picture of the whole set-up look at figure 143. It shows a very simple diagram of the connection between alternator and exciter. The alternator stator coils are pictured as three coils spaced 120° apart. The alternator rotor is shown as a single coil. Notice the two wires which run from the exciter armature to the alternator rotor. These wires carry the exciter voltage over to the alternator.

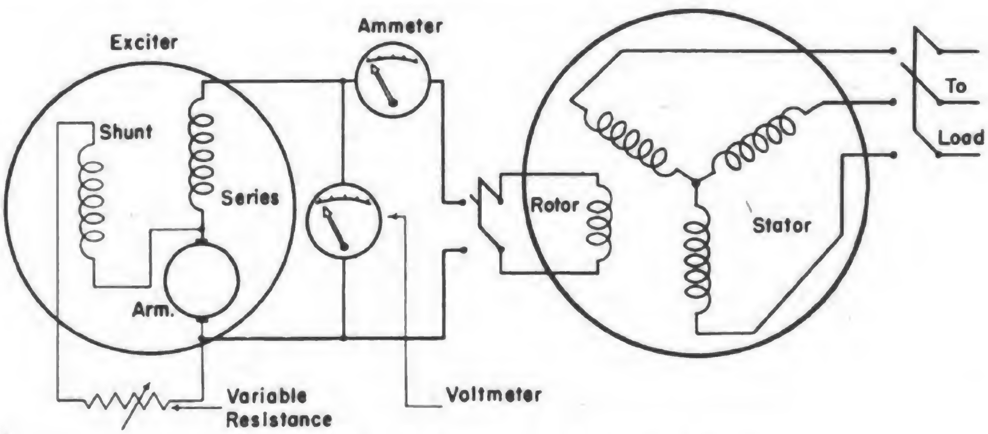


Figure 143.—Alternator and exciter diagram.

Check the shunt field and you'll find it in parallel with the armature—as it should be. The rheostat is also shown in series with the shunt field.

Suppose you wanted to increase the voltage output of the alternator. All you would have to do is DECREASE the resistance in the shunt field. The following would then take place:

1. The current would increase in the shunt field.
2. The exciter field strength would increase.
3. The rotating armature coils would have a greater e.m.f. induced in them.
4. The exciter voltage would increase.
5. The increase in exciter voltage would be impressed across the rotating field coils of the alternator.
6. The exciter current in the rotating field coils would increase.
7. The rotating field would increase in strength.
8. The alternator stator coils would have a greater e.m.f. induced in them.
9. The output of the alternator would increase.

READ THIS LAST

You've been given the basic principles of alternator operation. There is a lot more to it, of course. Don't think you have been left out on anything, though. You'll find more detailed explanations in chapter 7.

SUMMARY

Alternating current generators are called alternators.

Alternators may have a rotating armature and stationary field coils or stationary armature (STATOR) and rotating field coils (ROTOR).

Single-phase alternators are built for light, portable work.

Three-phase alternators are designed for heavy duty work.

Alternator field coils are energized by d.c. current from a d.c. generator. The d.c. generator is called an exciter.

The exciter is termed a direct-connected exciter when mounted on the alternator shaft.

The manufacturer's instruction book should always be referred to in the repair and maintenance of an alternator.

The essential points in the maintenance of alternators are:

1. To keep the insulation clean and dry.
2. To keep the electrical connections tight.
3. To keep the machine in good mechanical condition.

A regular schedule of cleaning and inspection should always be maintained.

Alternators for advanced base work use gas or Diesel engines for prime movers.

The frequency output of the alternator may be changed by controlling the speed of the prime mover.

The voltage output of the alternator may be varied by changing the exciter voltage.

QUIZ

1. What one word means alternating current generator?
2. What device is used to lower power-transmission losses over long stretches of wire?
3. What is the main difference in construction of large and small alternators?
4. How many separate windings must you add to a single-phase alternator in order to secure a three-phase current?
5. What do you call the d.c. generator which energizes the field windings on the alternator?
6. What is a unit called which furnishes the mechanical energy that drives the alternator?
7. How may you control the frequency of the alternator?
8. How may the voltage output of the alternator be adjusted?
9. List three essential points to remember about maintenance of alternators.
10. What publication should always be referred to in the maintenance and repair of the alternator?

CHAPTER 6

ALTERNATING CURRENT MOTORS

PUTTING INDUCTION TO WORK

You get a lot of satisfaction out of being able to answer a question that someone shoots at you. You're doubly satisfied if the question concerns your work as a Construction Electrician's Mate. It shows that you're "on your toes."

You will be number one man in any discussion on a.c. motor principles—if you've read *Electricity*, NavPers 10622. It wouldn't take much to start you off. Just let someone ask you the difference between d.c. motors and a.c. induction motors. That's all you need.

First, you would point out that a D.C. MOTOR uses a direct or STEADY CURRENT. A steady current circulating through the field coils produces a STEADY MAGNETIC FIELD. To get motor action it is necessary to send current through the armature coils. Because of the steady magnetic field this armature current can only come from the external circuit. It gets to the armature coils by way of the brushes and the commutator.

Second, you would point out that an A.C. INDUCTION MOTOR uses an alternating or CHANGING CURRENT. A changing current in the field coil causes a rising and falling magnetic field. That's where the difference between d.c. and a.c. motors comes in. With a changing magnetic field it isn't necessary to introduce

an external current into the armature coils. That means the elimination of the commutator and brushes. In fact, the rotating coils of an a.c. motor have no electrical connection with the external circuit.

You might have to explain how the changing magnetic field causes a current flow in the armature coils of the a.c. motor. You can do this easily enough by comparing the motor to a transformer. Figure 144 will help you put your point across.

The primary winding of the transformer represents the field windings of the motor. The secondary winding represents the armature windings. There is an air gap between primary and secondary of the transformer. This corresponds to the air gap between field poles and armature of the motor.

Alternating current is fed into the primary windings of the transformer. This causes a changing magnetic field to jump the air gap and link the turns of the secondary. As the magnetic field expands and contracts around the secondary, it cuts the secondary conductors. The result is an induced alternating e.m.f. If the secondary is short-circuited, the e.m.f. will cause an alternating current to circulate in the secondary coils. This secondary current is always opposite in direction to the primary current. Thus the magnetic fields that the secondary current produces will be OPPOSITE IN POLARITY to that set up by the primary current.

Now you're all set to clinch the argument. If the transformer can be compared to the a.c. motor, then the action in the motor is the same as that in the transformer. The alternating current in the field coils produces a changing magnetic field. The field links the conductors on the armature. This causes an induced e.m.f. in the armature coils. If the coils are shorted, a current will flow through them. A magnetic field is developed which is OPPOSITE IN POLARITY to that of the field coils.

THE ROTATING FIELD

As it now stands, you have the armature attracted to the field poles by action of their opposite polarity. Leaving it at that point, however, doesn't finish the story. What you're trying to get is motor action. You want that armature to

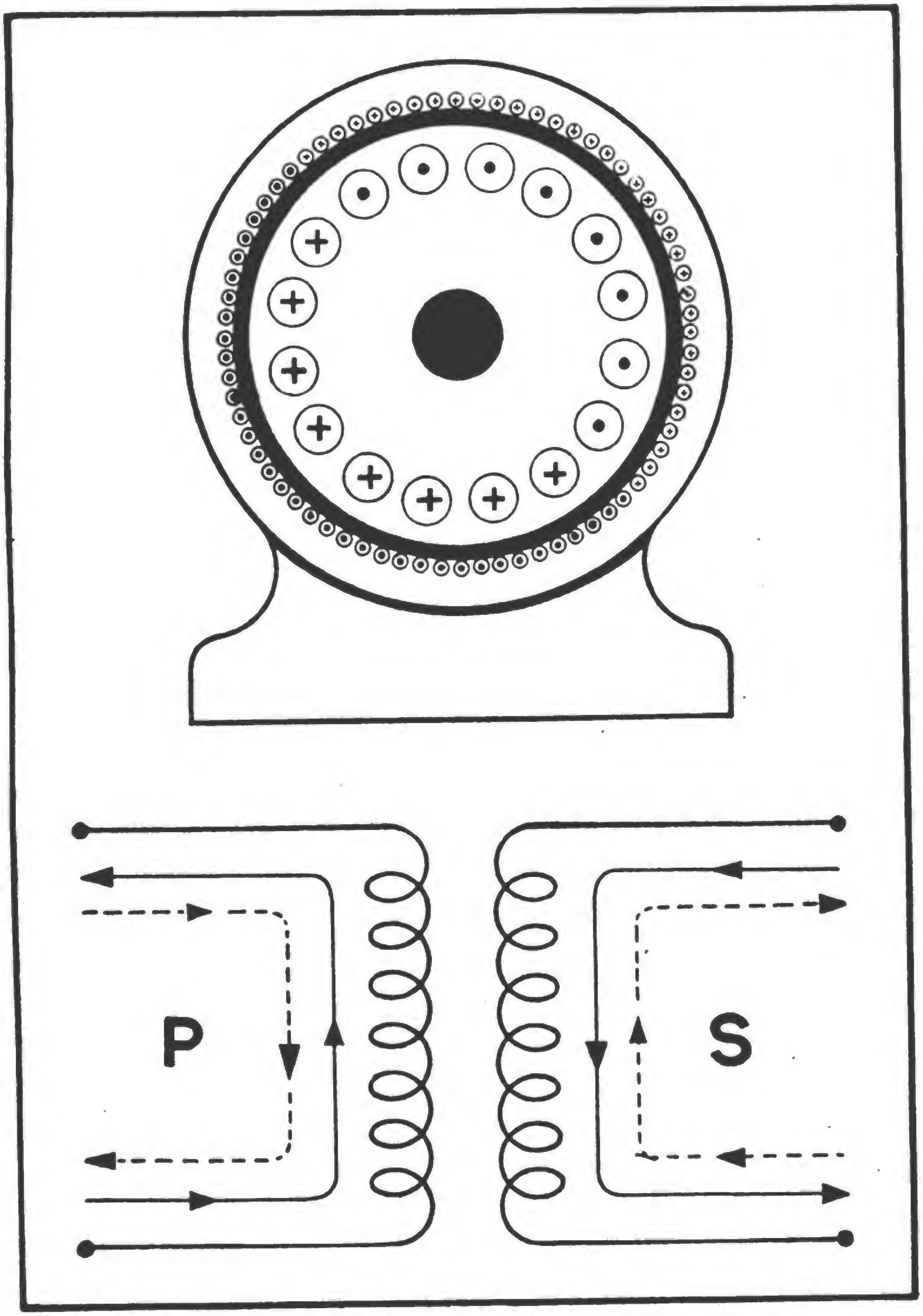


Figure 144.—Transformer action in an a.c. motor.

ROTATE, thus completing the change-over from electrical energy.

To get the armature to rotate you must rotate the field poles. When the field poles move they will drag the armature along with them.

A rotating field isn't new to you. Remember, it was part of the make-up of the alternator. The rotor of the alternator produced a rotating field. This rotating field swept across the stator coils inducing an e.m.f. If there were three sets of stator coils, a three-phase voltage was produced. If there was one set of stator coils a single phase voltage was developed.

If a rotating field will create voltages in stationary coils, then the same voltages introduced back into the stationary coils should be able to produce rotating fields. This holds true only IF a POLY-PHASE voltage is used. A SINGLE-PHASE voltage will NOT produce rotating fields.

Take a look at figure 145. It shows you how a poly-phase voltage produces a rotating magnetic field. A two-phase voltage is used to simplify the drawing. Three-phase voltage will produce the same result.

Each phase is impressed across a pair of poles. Each pair of poles produce a magnetic field when current travels through their field coils. The two magnetic fields react with each other to produce ONE RESULTANT FIELD. The arrow, shown in the center, represents that resultant field.

In step 1, the current in phase A is at a maximum, while that in phase B is zero. This produces a magnetic field between one pair of poles. The direction of the field is from north to south.

In step 2, the current in phase A begins to decrease, while current starts to flow in phase B. This point is 45 electrical degrees after step 1. Each pair of poles are now working. The RESULTANT FIELD HAS ROTATED 45° from its position in step 1.

In step 3, the current in each phase has advanced 90 electrical degrees. At this point, the current in phase *A* is zero; in phase *B* it is maximum. The RESULTANT FIELD HAS TURNED 90° from its original position.

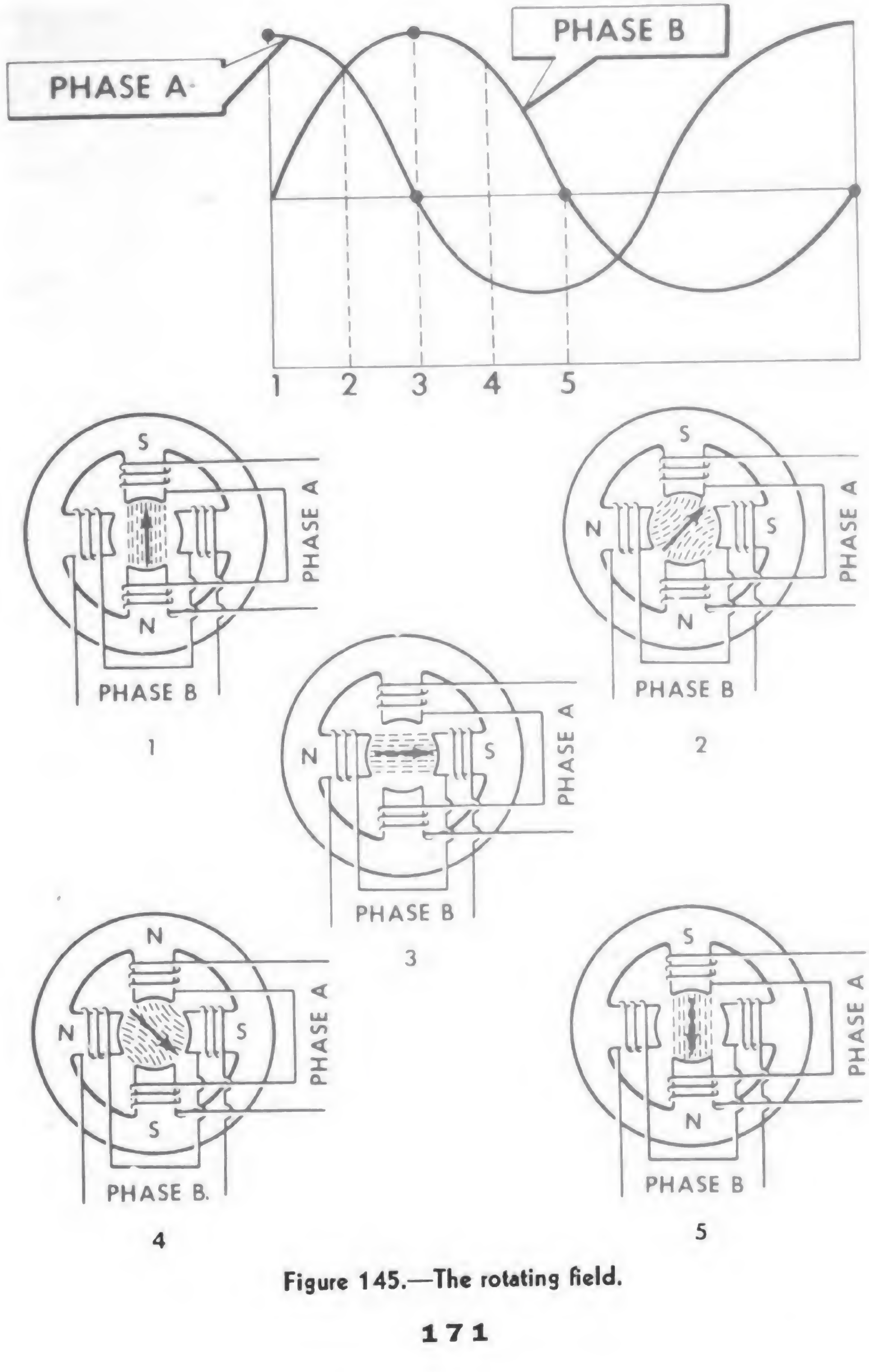


Figure 145.—The rotating field.

In step 4, the current in phase A has reversed its direction. This results in a reversal of the polarity in phase A. The current in phase B has decreased. All this takes place 135 electrical degrees from step 1. Thus, the RESULTANT FIELD HAS ROTATED 135° from its starting point.

In step 5, the field has moved to the halfway point. This corresponds to one half cycle of the alternating current. The current in phase B is zero. The current in phase A is maximum. The MAGNETIC FIELD HAS TURNED 180°.

It isn't necessary to show steps 6, 7, 8, and 9. It would just be a repeat of the first 5 steps. The fields of each phase would combine to complete the rotation of the resultant field back to its starting point.

Remember that rotor? It was attracted to the field by its opposite polarity. If the field rotates, the rotor will follow it along. It's as simple as that. Of course, the rotor will always lag the field by a certain amount. It would be impossible for the rotor to travel at the same speed as the field. If it did, there would be no cutting of lines of force and thus no torque.

Don't forget that single-phase voltage cannot produce a rotating field. Just imagine a single-phase current circulating through the field poles of the a.c. motor in figure 145. Instead of two separate circuits, there would be just one. All the field poles would be connected together. It's true the poles would change their polarity, but the changes would take place at the same time. Instead of a rotating field, you would have a pulsating, STATIONARY field.

THE THREE-PHASE MOTOR

You couldn't ask for anything better to work on than a THREE-PHASE INDUCTION MOTOR. Its rotating field allows for a simple construction. ROTOR, STATOR, and END PLATES are its three main parts and the best news is that the commutator won't give you a bit of trouble. There just isn't any in the three-phase motor!

Stator Construction

The STATOR of the three-phase motor is built exactly like the stator of the alternator. Instead of projecting poles, a slotted, LAMINATED CORE is used. The field coils fit into the slots.

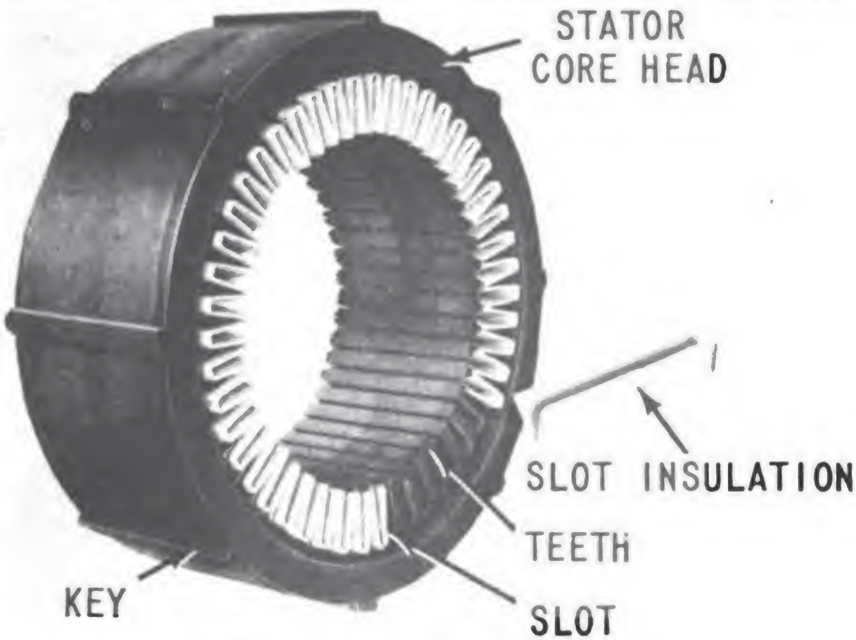


Figure 146.—A laminated stator core.

Figure 146 shows you a laminated stator core ready to receive the field coils. Notice the paper insulation inserted in·

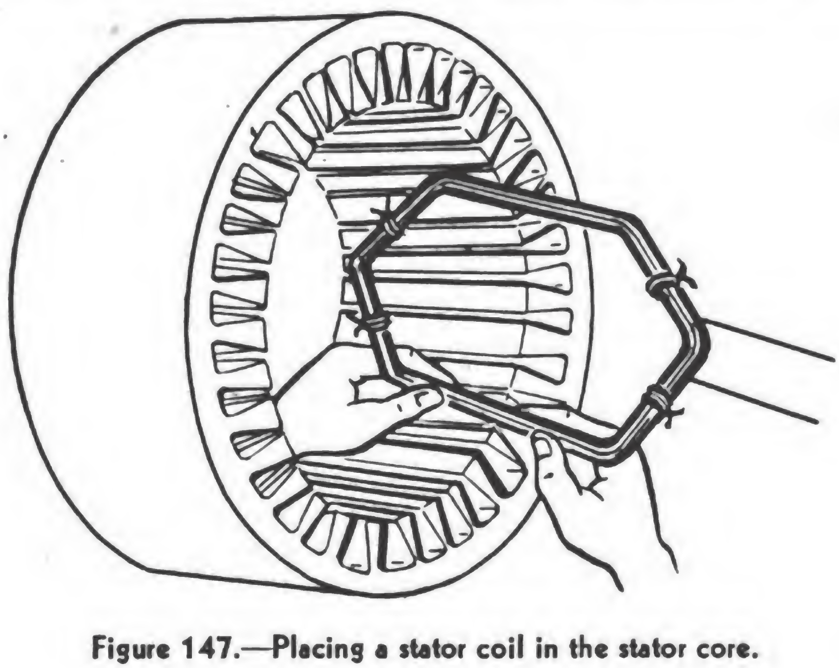
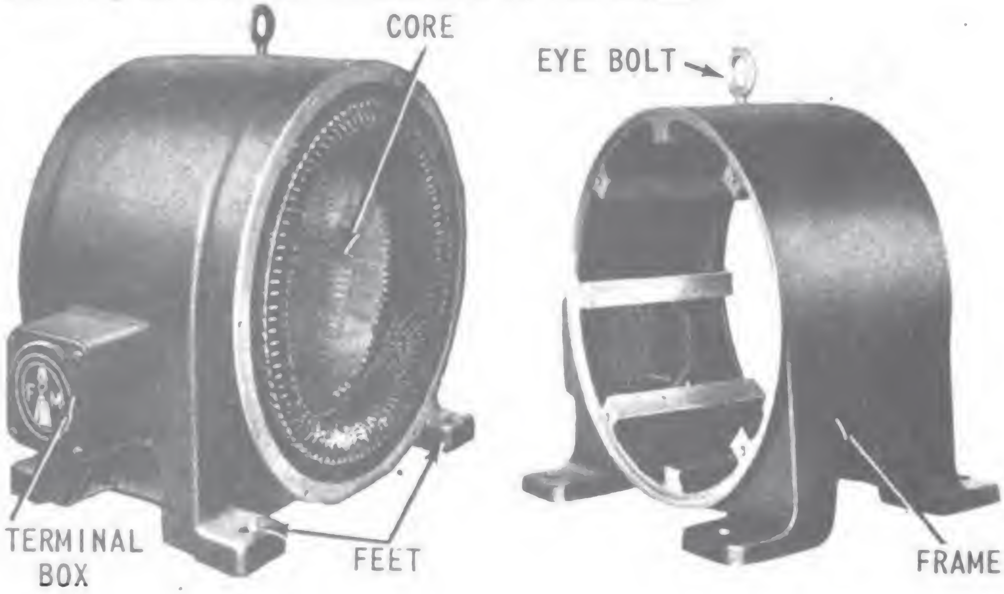


Figure 147.—Placing a stator coil in the stator core.

the slots. The insulation prevents shorts between field coils and stator core.

The field coils are preformed and then varnished and baked. Each coil is shaped to fit into its proper slot in the stator core. Figure 147 shows one of these coils being fed into a slot. After all the coils have been inserted in their proper slots they are connected together to form the three-phase windings. The completed stator core is also shown in figure 147.

The stator core is supported by the FRAME of the motor. The core is pressed into the frame and locked in place. Figure 148 shows you the frame ready to receive the stator core. It also shows you the core assembled in the frame.



FRAME - CORE IN PLACE FRAME

Figure 148.—Complete stator assembly.

Rotor Construction

The ROTOR of the a.c. motor plays the same part as the armature of the d.c. motor—it helps to produce torque, or turning motion.

You have the principles of rotor operation. Briefly, you've learned that:

1. The rotor acts as the shorted secondary of a transformer.
2. Alternating voltages are induced in the rotor windings by the rotating magnetic field of the stator.

3. Currents flow in the shorted rotor windings producing a magnetic field opposite in polarity to the stator field.

4. The rotor follows the rotating field.

Just how is the rotor constructed to make it resemble the shorted secondary of a transformer? Well, a transformer secondary is, basically, nothing more than a coil of wire wound on an iron core. And that's an exact description of the rotor! But, instead of one coil, there are many coils, each placed around the slotted, laminated iron core. Shorting the coils means merely connecting their ends together.

Figure 149 shows you the construction details of a shorted rotor. It resemblse a squirrel cage, so it is given the name of SQUIRREL CAGE ROTOR. It is the simplest and most commonly used rotor in a.c. motors. Those copper bars are the armature coils. They are shorted together by welding

Figure 149.—Squirrel-cage assembly.

them to copper end rings. In small motors the squirrel cage is usually cast as a complete unit.

To get transformer action, it is necessary to place the squirrel-cage assembly on a slotted, laminated, steel core. When this is done you obtain the complete rotor shown in figure 150. Notice those lugs which extend from the end rings. They act as fan blades. When the rotor revolves, the fan blades circulate a current of cooling air over and around the rotor and stator. This increases the efficiency of the motor.

At this point the construction of the squirrel-cage rotor might seem a little unusual. First of all, you probably are wondering how copper bars can take the place of ordinary armature coils. Actually, all that's being done is replacing small copper wires with one large copper wire. This is necessary because of the large currents which flow in the rotor. Small copper wire couldn't carry the load without heating up.

You might also have a question concerning the shorting of the copper bars. With all the bars connected to the same end rings it looks as if there is just ONE BIG SHORT CIRCUIT. But you want to remember that it's alternating current that is flowing in the rotor. Because of its action the a.c. sees each rotor bar as a separate circuit.

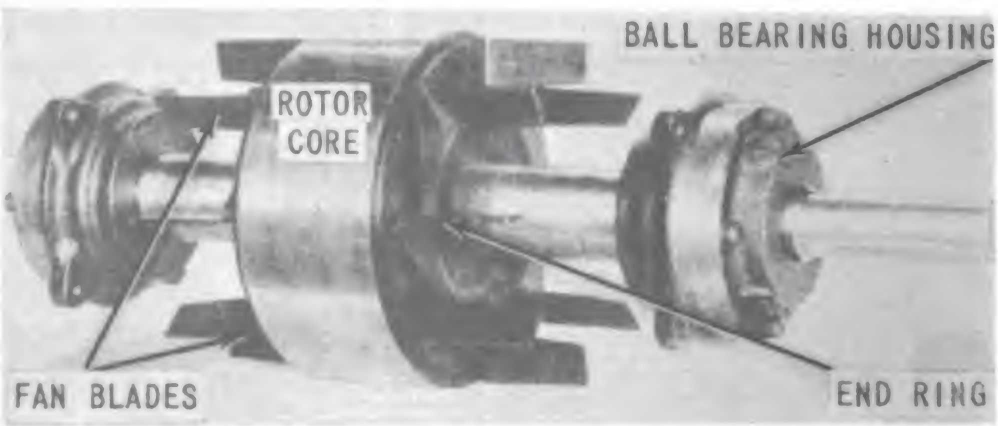


Figure 150.—A complete squirrel-cage rotor.

Question number three in your mind might be about the copper bars being laid DIRECTLY into the slotted core. It seems as if there is a direct short between the copper bars and the steel core—but there isn't. This is why. The steel core is LAMINATED. It is made up of many thin sheets of STEEL pressed together to form the core. The uneven contact between each sheet, although very small, presents a high resistance to a.c. current flow. The COPPER assembly of the squirrel cage, however, offers very little resistance. It's like having a high resistance in parallel with a low resistance. Thus, it isn't necessary to have insulation between the copper bars and the core.

End Plate Construction

You are already familiar with the job of the end plates. In a d.c. motor they are used to support the armature shaft and the brush rigging. A three-phase motor has no brush rigging so the end plates simply act as a support for the rotor shaft. The bearings which reduce the turning friction of the shaft are seated in the end plates.

Figure 151 shows you the rotor placed inside the stator. The end plates have been swung aside so you can get a clear picture of the rotor.

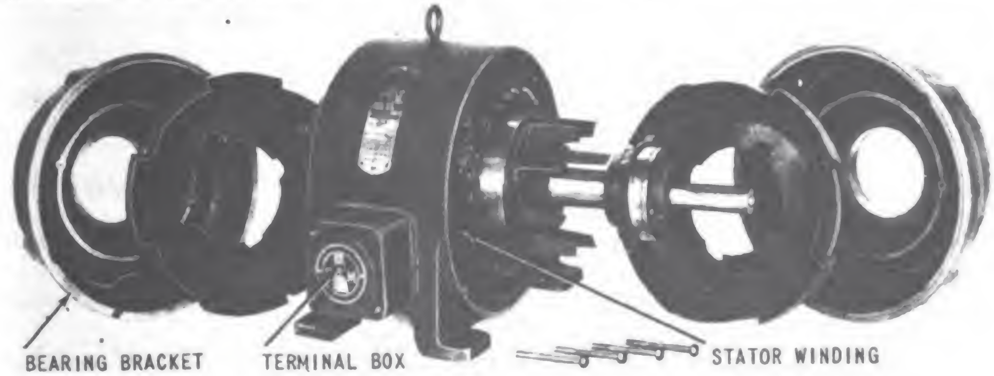


Figure 151.—Rotor placed inside of stator.

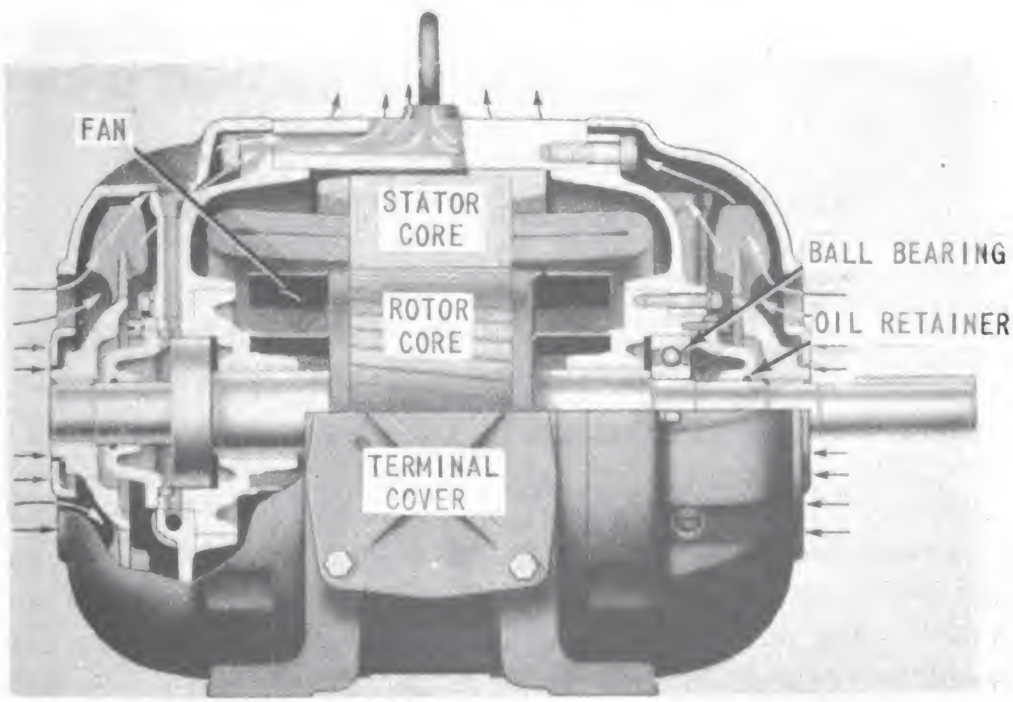


Figure 152.—Complete three-phase motor.

With the end plates securely bolted to the motor frame you have the complete motor shown in figure 152. A section has been cut away so that you can see inside of the motor. You can easily check the positions of the rotor, stator, and bearings with respect to each other. Also, note the arrows which indicate the direction of the air flow used to cool the motor.

Maintenance

Your maintenance of the three-phase motor will be concerned mainly with the bearings. Either sleeve or ball bearings are used. It's up to you to maintain a regular inspection schedule.

Keep a close eye on bearing temperatures. If a sleeve bearing overheats it could mean that there isn't enough oil. Dirt in the oil or poor rotation of the oil ring will also cause overheating. A ball bearing will overheat, not only if there isn't enough grease, but if there is too much grease.

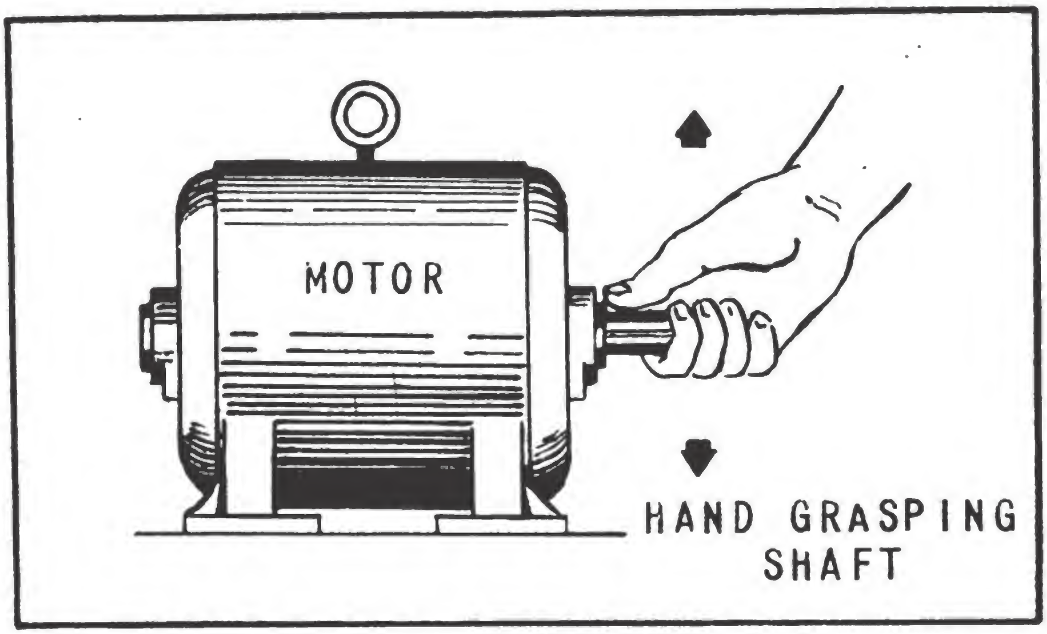


Figure 153.—Testing for worn bearings.

Bearings wear out eventually. A worn bearing will cause the rotor shaft to move out of alinement. If the rotor shaft is out of line, the rotor will rub against the stator core. You can imagine the damage this would cause. You can prevent this from happening by checking bearing wear at frequent intervals.

Checking the bearings on small motors is easy. You simply grasp the rotor shaft and try to move it up and down. This method is shown in figure 153. If you feel any play in the shaft it's an indication of worn bearings.

The rotor shafts on large motors are too heavy to lift. Thus, you will have to check the air-gap clearance between rotor and stator. That means the removal of one end plate. You use a FEELER GAGE for this operation. A feeler gage is made up of thin metal blades of varying thickness. Use the blade which will just fit between the rotor and stator. Move the blade completely around the rotor, making sure the air gap is the same at all points. If there is a difference in gap thickness, it indicates a worn bearing or a bent shaft. Figure 154 shows you the feeler gage and where it is inserted in the motor.

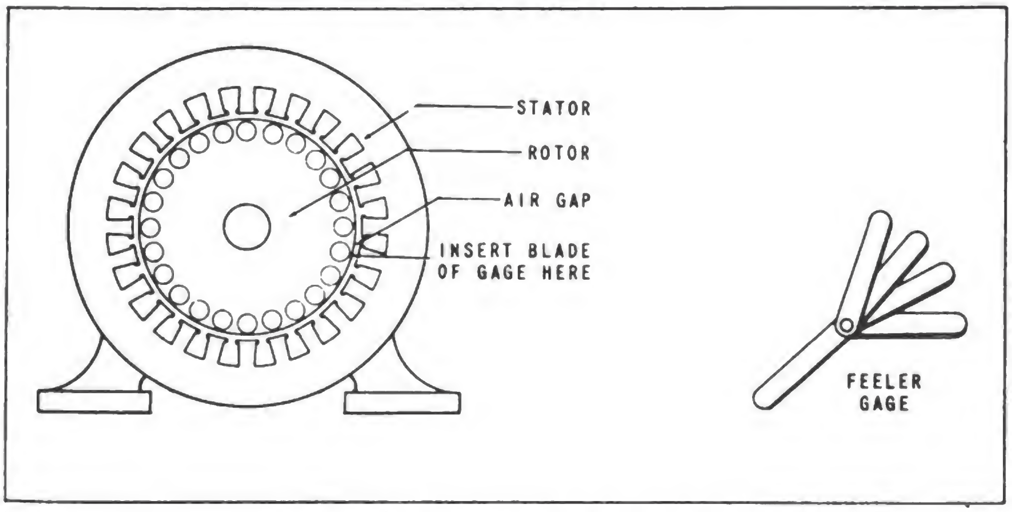


Figure 154.—Using the feeler gage.

Don't forget that keeping your motor clean is important, too. If the motor is working in a dirty location, frequent cleanings will reduce repair and overhaul. Compressed air is your best bet to remove dirt and other material. Just be sure your air pressure isn't over 50 pounds per square inch. Too much air pressure will tear away the insulation on the coil windings.

SINGLE-PHASE MOTORS

A three-phase motor has three sets of field coils mounted on the stator core. A three-phase voltage will cause currents to flow in the field coils. At any one time each set of field

coils will be energized by currents of different strengths. In one set the current may be very strong, in the other it may be zero, and in the third the current may be weak. Thus, each set of field coils produces a magnetic field whose strength is different from those in the other sets. These CHANGING fields combine to produce a resultant field which ROTATES around the stator core. The rotor follows the field around.

Now take a look at figure 155. It shows you a simplified wiring diagram of a SINGLE-PHASE motor. Notice that there is just one set of stator windings. The rotor is of the squirrel-cage type and it is at a standstill. A single-phase voltage is being impressed across the field-coilleads, L_1 and L_2.

The alternating current which flows through the field windings is changing in magnitude, first in one direction and then in the other. This causes a magnetic field to expand and

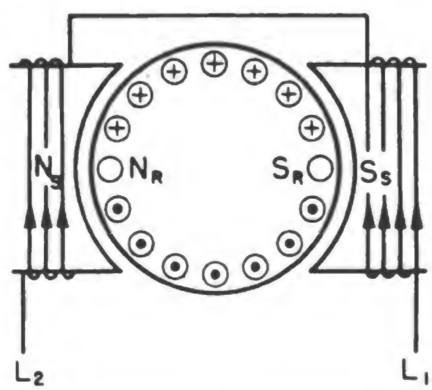


Figure 155.—Rotor currents in a single-phase motor at standstill.

contract across the rotor windings. When the lines of force cut the rotor bars they induce a voltage in them. Since the rotor bars are shorted, current will flow in each bar. These currents will set up their own magnetic field, which will OPPOSE that of the field coils.

You're interested in seeing how those fields look. So, suppose you stop the action at a certain instant of time. For example, when the current in the field coils is flowing in the direction shown in figure 155. At this particular time the stator poles have a north and south pole, as indicated. The induced currents in the rotor will flow in opposite directions in each half

of the rotor windings. The polarity of the rotor field is opposed to that of the field coils.

Opposing poles try to push each other away. So why doesn't the rotor start to turn? The rotor will not turn because the opposing poles are DIRECTLY OPPOSITE each other. That north pole of the stator, for example, is trying to push the north pole of the rotor to the right AND to the left. Both forces are EQUAL and OPPOSITE to one another. They cancel each other out and the rotor STANDS STILL.

It doesn't make any difference as to the direction or strength of the current in the stator coils. The polarity of the rotor field at a standstill will always be directly opposite that of the stator. As you suspected, A SINGLE-PHASE MOTOR WILL NOT START BY ITSELF. It needs some EXTRA inducements to get it going. Once it gets under way it will continue to operate.

Give that rotor in figure 155 a flip with your hand. As it rotates it will CUT lines of force of the stator field. An induced e.m.f. is set up in the stator windings. This e.m.f. causes a current to flow in the rotor in the direction shown in figure 156.

Notice the position of the rotor field with respect to the main field. The rotor poles are 90 degrees out of phase with those of the main field. That's all you need for a rotating field and

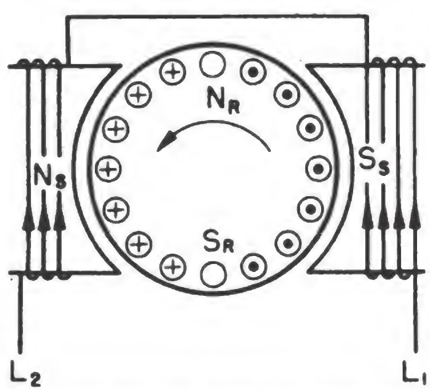


Figure 156.—Rotor currents in asingle-phase motor when rotating.

that is exactly what is produced. As a result, the rotor will continue to rotate. But don't forget that it was necessary to give the rotor a push to get it going. Without the initial start the single-phase motor is a dead duck.

THE SPLIT-PHASE MOTOR

Construction

The SPLIT-PHASE MOTOR is a single phase job. Figure 157 shows you the exploded view of this type of motor. At first glance it looks like the old familiar induction motor. You've got the squirrel-cage rotor, the stator, the motor frame, and the end plates, and there are no commutators, slip rings, or brushes to worry about.

Take a closer look, though, and you'll find something new has been added. First of all, there's an extra winding on the stator core. It is called the STARTING WINDING. Second, there are two parts, marked *A* and *B*. Both parts make up the CENTRIFUGAL SWITCH.

The STARTING WINDING is just another set of field-coil windings laid in the stator slots along with the main or running winding. They are placed in the core at right angles to, and in parallel with, the main windings. Figure 158 is a simplified diagram of this arrangement.

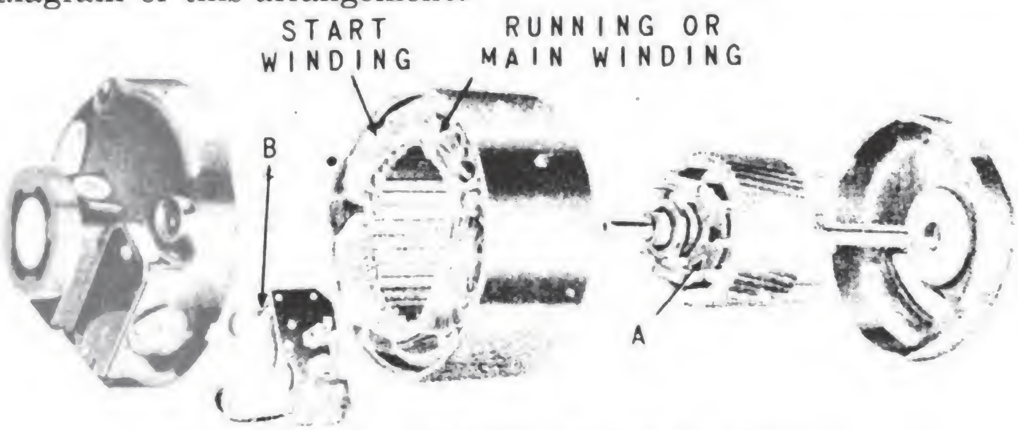


Figure 157.—Exploded view of a split-phase motor.

From figure 157 you can also see the position of the CENTRIFUGAL SWITCH in the stator circuit. It is in series with the starting winding. When the switch is closed, the starting winding is being energized by the line. When the switch is open, the starting winding is disconnected from the line.

Operation

The starting winding is that extra inducement needed to get the rotor turning. The winding itself is made up of a few

turns of wire. This produces a LOW INDUCTANCE STARTING WINDING.

The main, or running, winding is constructed of many turns of wire. This combination means a HIGH INDUCTANCE RUNNING WINDING.

Before the motor is started, the centrifugal switch is closed. Both starting and running windings are placed directly across the line.

Essentially, this is what happens when the line switch is turned on:

1. The a.c. line voltage is impressed across both windings at the same time.

2. The a.c. line voltage tries to force alternating current through each winding.

3. The running winding is of high inductance. High inductance offers a high resistance to alternating current. Thus, the current in this winding is being held back.

4. The starting winding is of low inductance. Low inductance offers a low resistance to alternating current. Thus, the current in this winding is allowed to go on through.

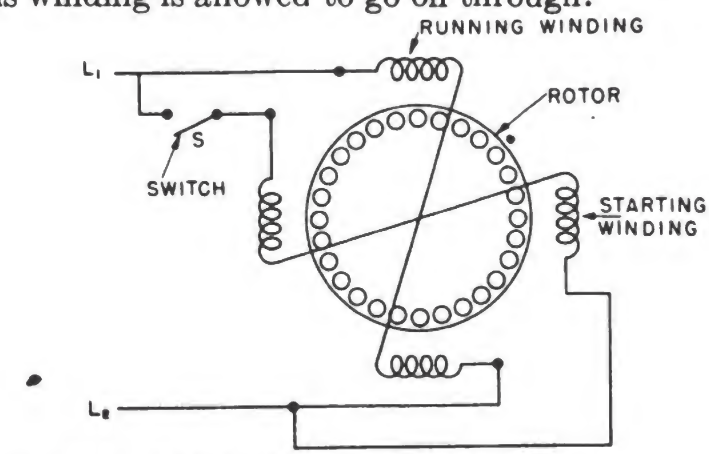


Figure 158.—Connections for a split-phase motor.

As a result, you have the current in the running winding LAGGING the current in the starting winding. Each current will produce a magnetic field as it travels through the windings. These magnetic fields will be OUT OF PHASE with each other. Since the windings are set 90° apart on the stator core, a weak ROTATING FIELD is produced.

The rotating field will drag the squirrel-cage rotor along with it. You've accomplished your purpose in getting the rotor started.

Once the rotor has attained enough speed it won't need the rotating field to keep it going. The shorted bars of the squirrel cage cutting across the field of the running winding will maintain rotor motion. And that's where the centrifugal switch enters the picture. The centrifugal switch AUTOMATICALLY disconnects the starting winding from the line. This takes place after the motor has reached 75 to 80 percent of its full speed.

Have you ever driven a car around a sharp curve at a fast rate of speed? Although you have the wheels turned in the direction of the curve, it seems as if an invisible hand is forcing the car off the road. That invisible hand is CENTRIFUGAL FORCE You'll find centrifugal force doing its job on any

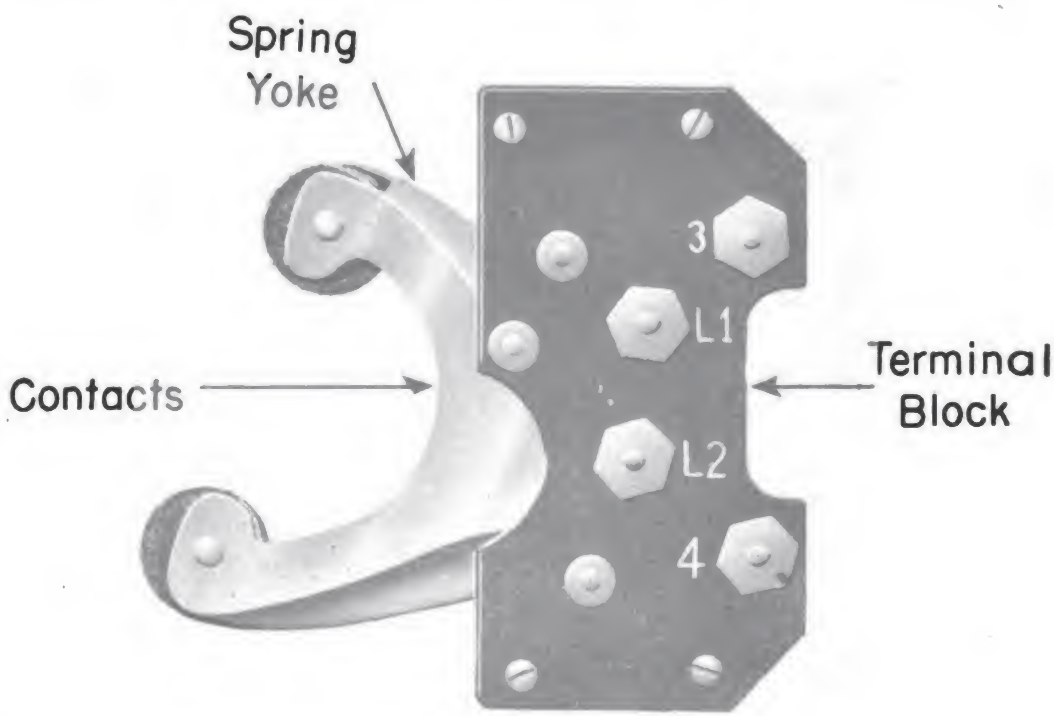


Figure 159.—Stationary part of centrifugal switch.

object which isn't traveling in a straight line. Since the rotor of a motor follows a curve, you can expect centrifugal force to be working on it, too.

Usually, centrifugal force is the bugaboo of the motor repairman. It is always present, exerting a strain on all parts of the rotating rotor. Just let a rotor bar become loose and it won't be long before it's torn completely from its slots. In a split-phase motor, however, centrifugal force does some good. Its action causes the centrifugal switch to work.

The centrifugal switch is made up of two parts: a stationary part which is mounted on the end plate or the frame, and a rotating part which is placed on the rotor. Figure 159 gives you a closer view of the stationary part of the switch. Notice that it contains the contacts or switching arrangement.

The action of the centrifugal switch is shown in figure 160. With the motor at a standstill the contacts are kept closed by the pressure of the rotating part. As the motor approaches 75 percent of full speed, centrifugal force pulls the rotating part away from the spring yoke. As soon as the pressure is released, the contacts open, disconnecting the starting winding. Now your motor is operating as a normal single-phase job.

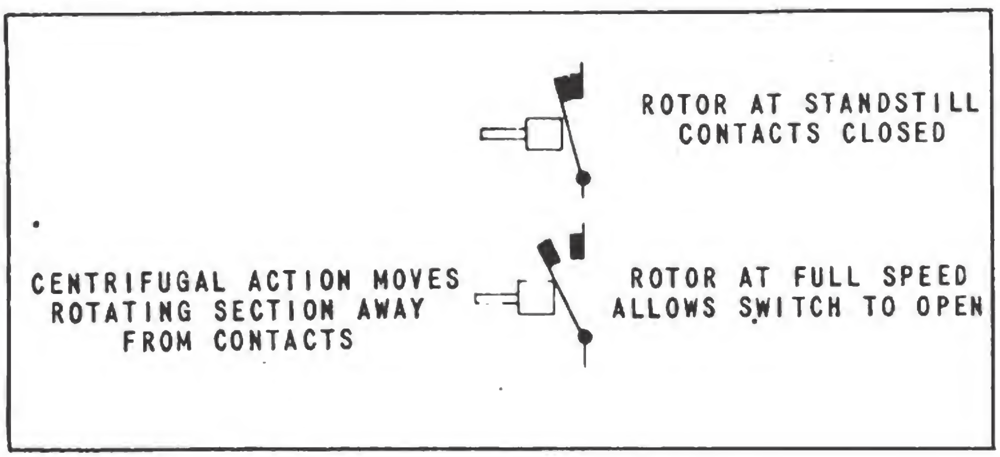


Figure 160.—Centrifugal switch action.

Maintenance

Your maintenance procedure on the split-phase motor will not vary from the other type of motors you have studied. The fact that the split-phase motor has no commutator or brushes makes your job a little easier.

Split-Phase Motor

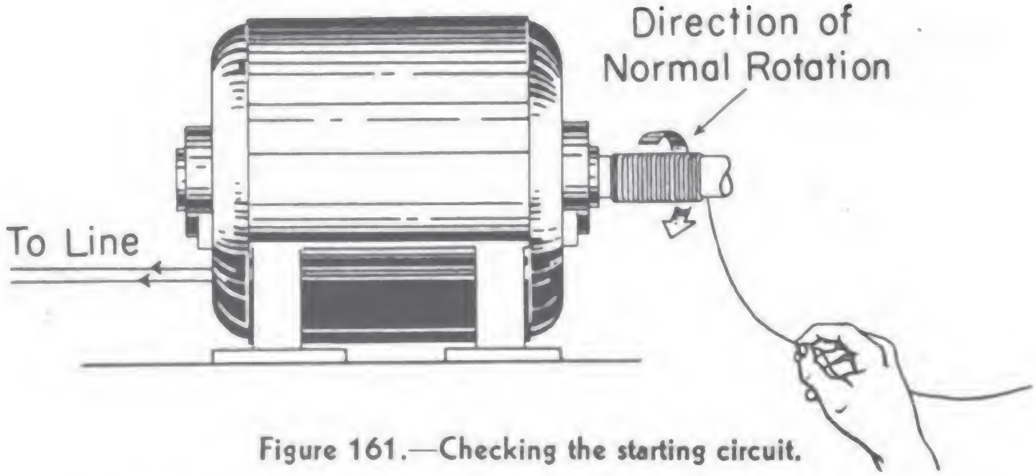


Figure 161.—Checking the starting circuit.

The centrifugal switch might cause you a little trouble. If the contacts get dirty, the switch will act as an open circuit. The starting winding will be out of the circuit and the motor won't start.

You can check the starting circuit by rotating the motor by hand. In this case, you are taking the place of the starting winding. Figure 161 shows you the method. A cord is wound around the rotor shaft in the direction of normal motor rotation. By pulling the cord, you will start the rotor turning. Now turn the line switch on. If the motor keeps on running, then you know the trouble is in the starting circuit.

THE CAPACITOR MOTOR

The capacitor motor falls into the split-phase motor class. It does the same job as the split-phase motor of "splitting" a single-phase current for starting purposes. It has a starting winding, a running winding, a centrifugal switch, and a CAPACITOR.

The capacitor, or condensor, is what makes the capacitor motor different from the split-phase motor. Figure 162 shows you where the capacitor fits into the motor circuit. It is placed in series with the starting winding. Its action causes the current in the starting winding to lead that in the running winding. The two out-of-phase currents produce two corresponding out-of-phase magnetic fields. A rotating field is produced and the

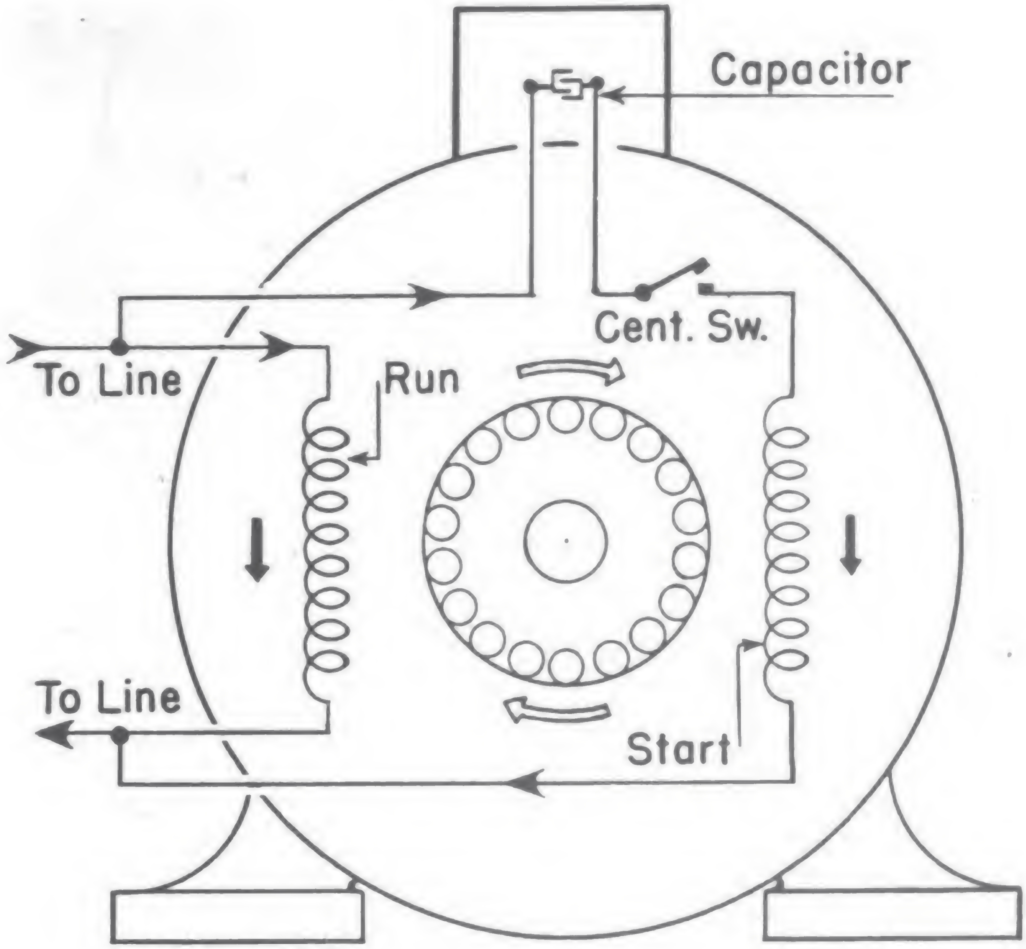


Figure 162.—Capacitor motor circuit.

rotor starts to turn. The centrifugal switch does its job of removing the starting circuit after the motor comes up to normal speed.

THE REPULSION MOTOR

Construction

The repulsion motor works on single-phase current just like the split-phase motor. It does it in a little different way so its construction is slightly different. First of all, it doesn't use a squirrel-cage rotor. It has a rotor, all right, but instead of copper bars, you'll find ordinary armature COILS. You'll also discover the coil ends connected to a COMMUTATOR. All of this should sound familiar to you because it is an exact description

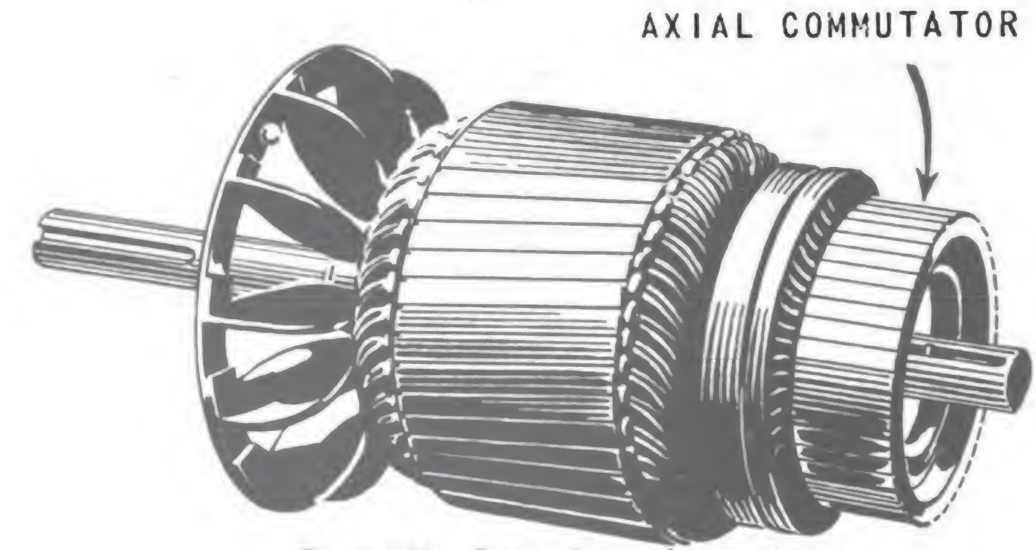


Figure 163.—Rotor of a repulsion motor.

of the armature of a d.c. motor. Just to refresh your memory the rotor is shown in figure 163.

Wherever you find commutators you'll find brushes. The repulsion motor is no exception to this rule. The unusual feature of the brush set-up is the fact that all the brushes are connected (shorted) together. There is no connection between brushes and the external circuit. Figure 164 shows you a sim-

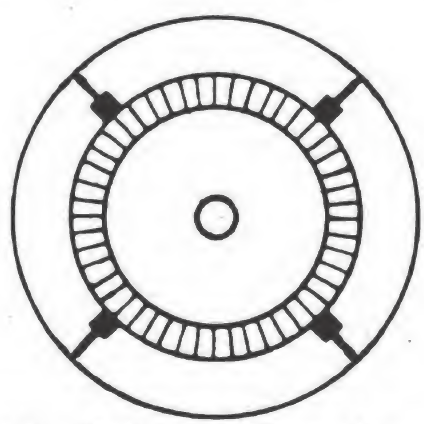


Figure 164.—Brush circuit of a repulsion motor.

plified view of the short-circuited brushes riding on the commutator. Usually the pigtails of the brushes are connected to a one-piece metal brush rigging.

The stator construction of the repulsion motor shouldn't give you any trouble. It's just like that of the split-phase

motor except for one important detail—there is no starting winding. All that you'll find in the stator slots will be the main, or running, winding.

Operation

The fact that there is no starting winding in the repulsion motor sounds a little strange. Just where does the rotor get that initial push to start it going? Well, what does the repulsion motor have that the split-phase doesn't? That's right, short-circuited brushes. And that's what STARTS the motor and KEEPS it running.

Just how all this is accomplished is shown in figure 165. To

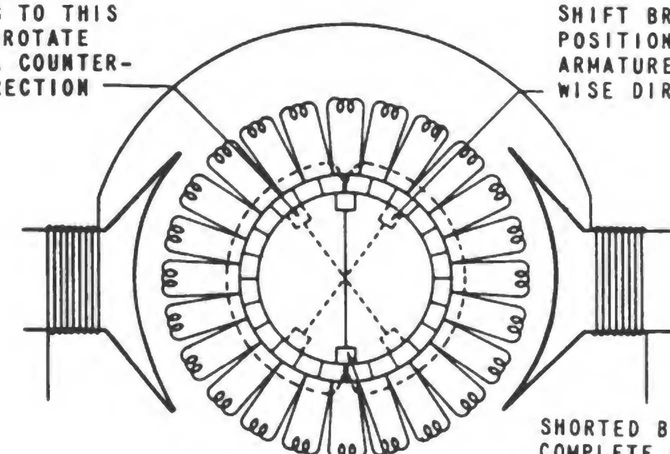


Figure 165.—Repulsion motor operation.

simplify the drawing, the brushes are shown riding on the inside of the commutator. Alternating current in the stator winding produces an expanding and contracting magnetic field. This field links the rotor coils inducing a voltage in them. The coils on each side of the short-circuited brushes form two closed paths with the brushes. The induced voltages will cause heavy currents to flow through the coils and brushes.

Suppose the brushes are positioned halfway between the poles. The currents flowing in each half of the motor will be EQUAL and OPPOSITE. The net effect is a zero torque and the rotor will not move. Now move the brushes to a new position just to the left. Here you will find the currents still flowing in opposite directions in each half of the armature, but they will

be of UNEQUAL strength. Poles will appear at each of the brushes which will be REPELLED by those of the stator field. As a result, a torque is produced which turns the rotor. Since the brushes remain in one spot, there will always be a repulsion present and the rotor will continue to turn.

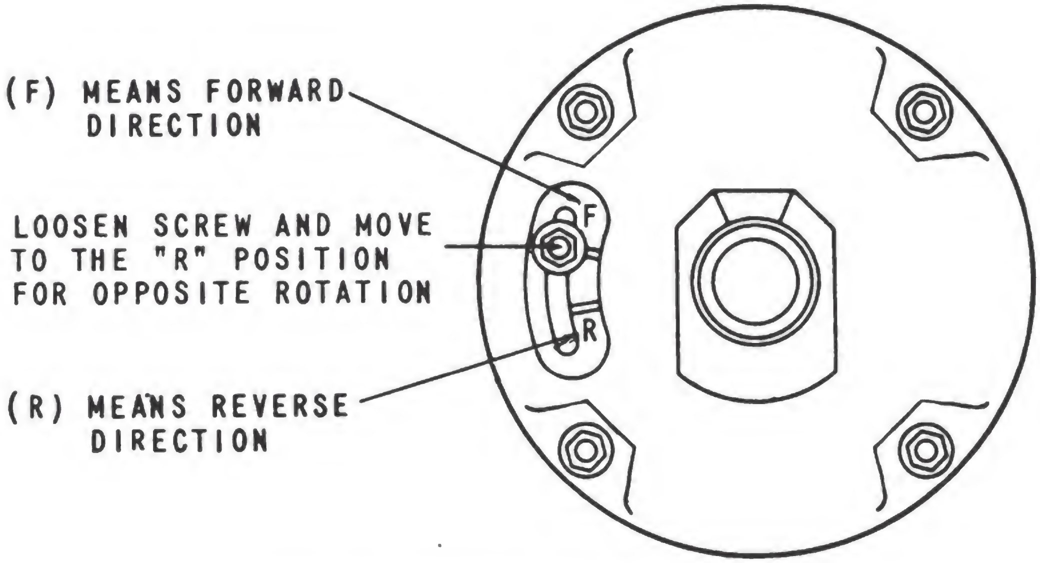


Figure 166.—Reversing the repulsion motor.

The position of the brushes with respect to the vertical plane will determine rotor direction. When the brushes are to the LEFT, the rotor will turn COUNTERCLOCKWISE. Moving the brushes to the RIGHT of the vertical plane will cause the rotor to rotate in a CLOCKWISE direction.

In some repulsion motors you will be able to change rotor direction without removing the end plate. The movement of the brush rigging is controlled from the outside. Figure 166 shows you the appearance of the end plate. Note the manner in which the position of the brush holder is changed.

Maintenance

Your regular motor-maintenance procedure applies to the repulsion motor as well as to other types. Remember that the brushes and commutator will need your constant attention.

REPULSION-START, INDUCTION-RUN MOTOR

A REPULSION MOTOR has the advantage of high-starting torque. Its disadvantage lies in its varying speed with changing loads. The INDUCTION MOTOR has the disadvantage of low-starting torque. Its advantage lies in its constant speed with changing loads.

Combine the motors in the right manner, and you keep the advantages and lose the disadvantages. This is done in the REPULSION-START, INDUCTION-RUN MOTOR.

Construction

When you read about the split-phase INDUCTION MOTOR, you discovered that its main feature was a SHORTED ROTOR. When you read about the REPULSION MOTOR you discovered that its main feature was an ordinary drum-wound rotor with a commutator and SHORTED BRUSHES. Just how are these combined to produce the repulsion-start, induction-run motor?

Figure 167.—Unassembled repulsion-start, induction-run motor.

Figure 167 will help you answer this question. It shows an unassembled repulsion-start, induction-run motor. There's nothing unusual about the stator construction. It consists of the well known single-phase field coils embedded in the slotted

surface of the stator. The usual end plates (bearing brackets) are also present.

Now take a look at the rotor. At first glance it looks like an ordinary drum-wound type used in a repulsion motor. Each coil is connected to a commutator bar, and the brushes are shorted together. But, check a little closer and you'll find an added feature. It's a part labeled "short-circuiting fingers." It is placed on the rotor shaft just to the right of the commutator.

Figure 168 gives you a close-up shot of this new addition. It is made up of a large number of separate copper "fingers."

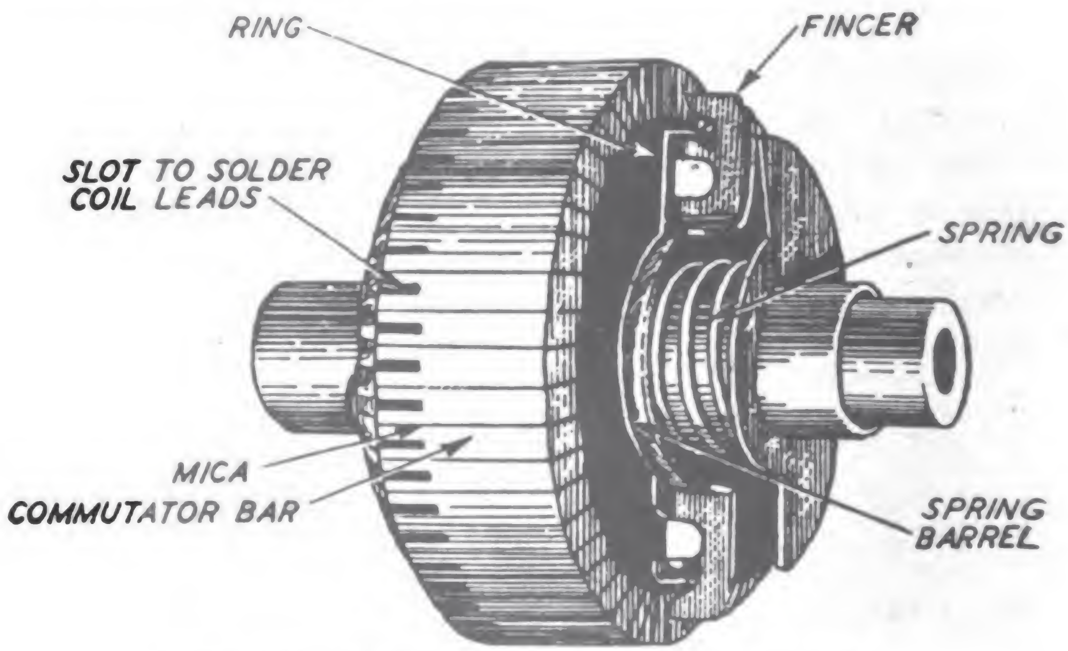


Figure 168.—Cut-away section of short-circuiting switch.

The fingers are assembled in a housing and kept in position by a spring, mounted under tension in a spring barrel. The whole device is tagged with the name of SHORT-CIRCUITING SWITCH.

Operation

When the motor is at a standstill, the copper fingers are NOT in contact with the commutator. Thus, when you close the line switch you are starting with a repulsion motor. The shorted brushes riding on the commutator produce a repulsion between rotor and stator fields. A HIGH-STARTING TORQUE is obtained.

As the motor reaches approximately 75 percent of its full speed, the short-circuiting switch comes into play. At this speed, centrifugal force is great enough to force the loosely held fingers against the commutator segments. Fingers, rings, and commutator segments form a short-circuit. Since the rotor coils are connected to the commutator segments, they too are short-circuited. A shorted rotor means a change-over to an induction motor. An induction motor means CONSTANT SPEED operation.

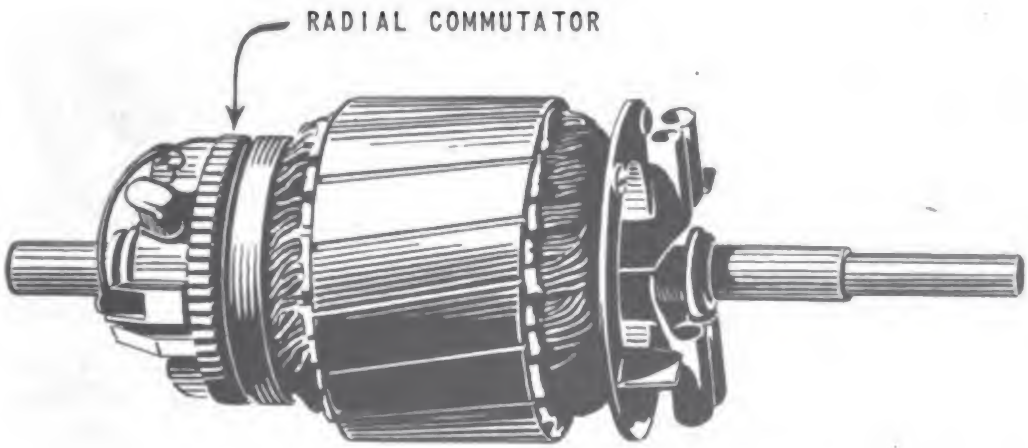


Figure 169.—A rotor with a radial commutator.

You have probably noticed an important detail about the motor just discussed. Namely, that the brushes are riding on the commutator at all times. You start getting some brilliant ideas. Idea number one: the brushes are only used to start the motor. Idea number two: why not reduce brush and commutator wear by lifting the brushes away from the commutator? Idea number three: lift the brushes away at the same time that the rotor is short-circuited. Idea number four: use centrifugal force to do the work.

All good ideas, but just a little late. You'll find that a motor using these principles has already been built. Figure 169 shows you the rotor construction. It uses a RADIAL COMMUTATOR. On a radial commutator, the brushes ride on the vertical surface instead of the horizontal surface. This type of construction makes it easier to lift the brushes away.

The difference between a radial commutator and the ordinary type is shown more clearly in figure 170. The ordinary, or AXIAL COMMUTATOR, is shown on the left. Notice that its bars are parallel to the shaft. The radial commutator is shown on the right. Its bars are perpendicular to the shaft.

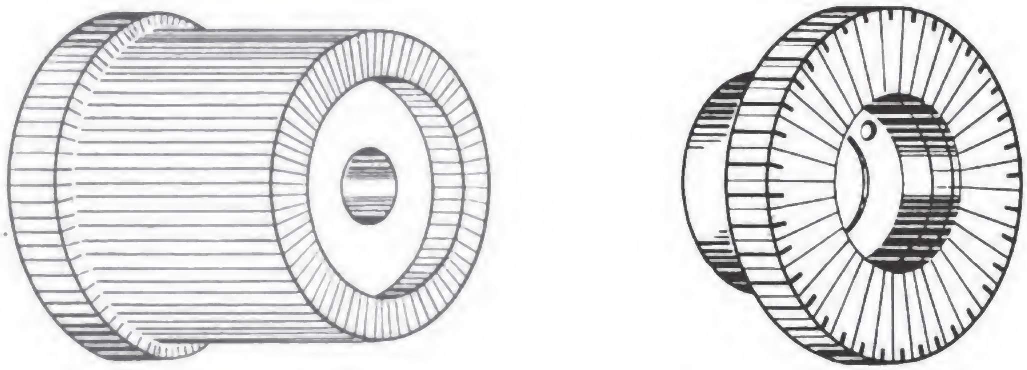


Figure 170.—Axial and radial commutators.

To get a good idea of how the brush-lifting mechanism works, look at figure 171. It's the exploded view of the rotor shown in figure 169. Each part is shown in its proper position before assembly. Notice the two push rods sticking out just below the commutator. They extend parallel to the shaft and connect back to the centrifugal mechanism. The rods also push against the short-circuiting necklace, and the brush rigging. The push of the rods is balanced by the push of the governor spring.

When the motor first starts up these conditions exist:

1. The short circuiting necklace is not in contact with the commutator.

2. The brushes are pressed against the commutator by the action of the governor spring.

When the motor reaches about 75 percent of its full speed the following takes place:

1. Centrifugal force pushes the governor weights outward.

2. The outward thrust of the governor weights causes the push rods to move forward.

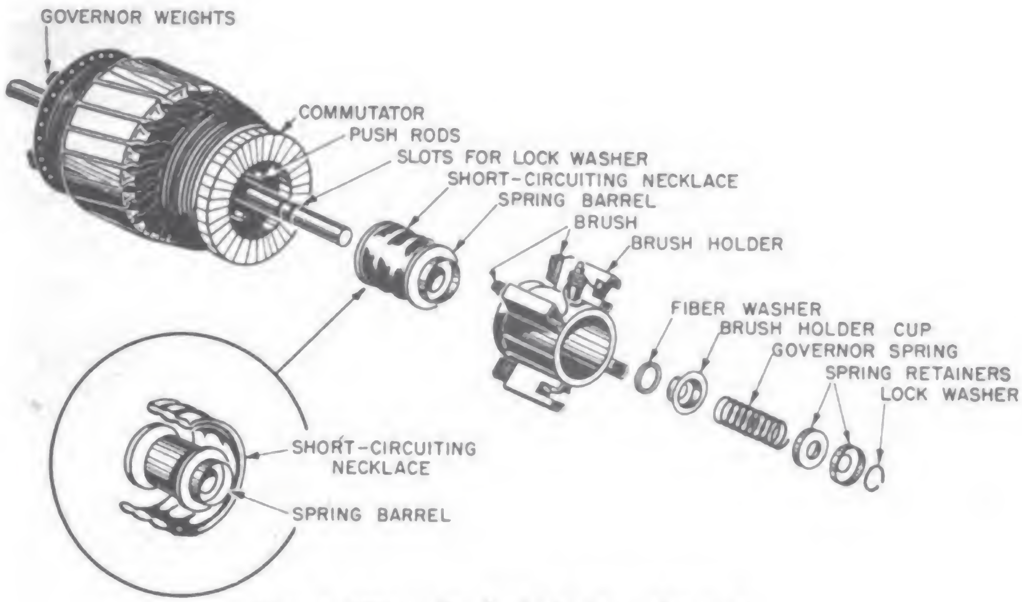


Figure 171.—Exploded view of a rotor.

3. The movement of the push rods force the short-circuiting necklace into position.

4. At the same time, the brush rigging is pushed away from the commutator.

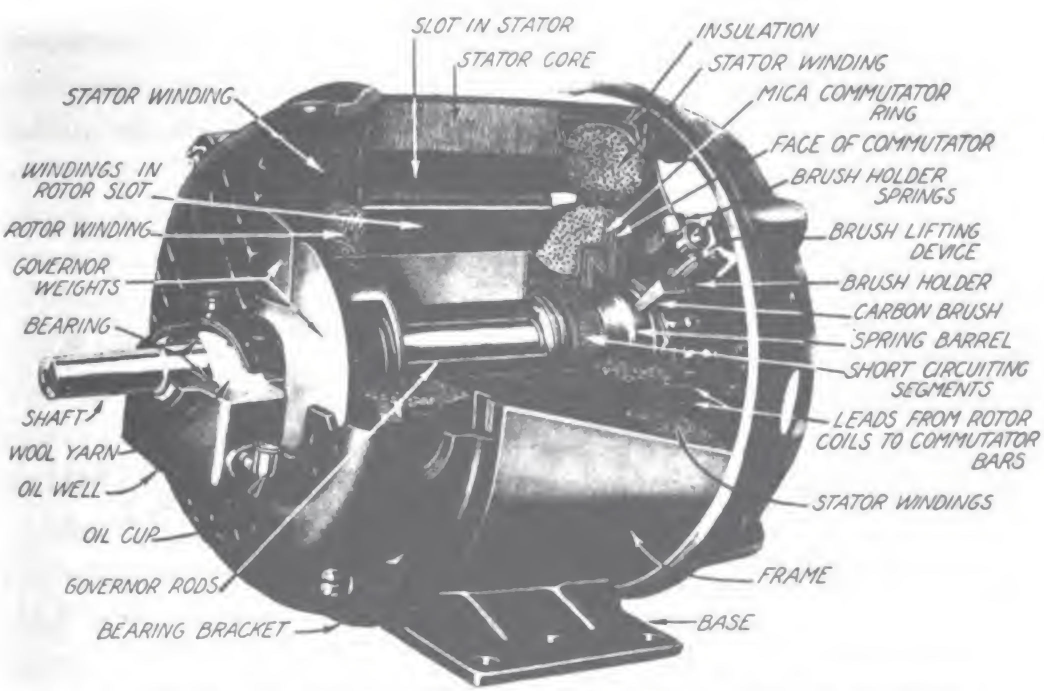


Figure 172.—Completely assembled repulsion-start, induction-run motor.

5. Centrifugal force causes the copper segments of the necklace to move outward. They contact the inner surface of the commutator and short the bars together.

The brush-lifting device on repulsion-start, induction-run motors is usually found on the larger jobs. A good cut-away view of a completely assembled motor of this type is shown in figure 172.

Maintenance

The maintenance of the repulsion-start, induction-run motor runs true to form. Just observe the following points and you can't go wrong.

1. Maintain a clean commutator surface.
2. Check brush length frequently.
3. See that the brushes press at all points on the commutator surface.
4. Keep the governor mechanism in good condition by cleaning and oiling. Use oil sparingly.
5. Keep the bearings well lubricated.

REPULSION-INDUCTION MOTOR

The short-circuiting necklace does its job well in the repulsion-start, induction-run motor. But like all other mechanisms it can get out of order. The REPULSION-INDUCTION motor

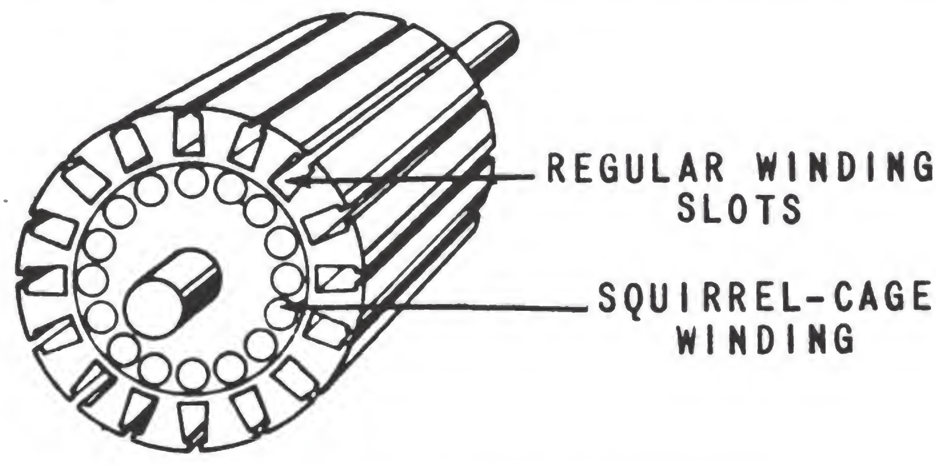


Figure 173.—Rotor of repulsion-induction motor.

uses a more positive method. The stator has two sets of windings. One, an ordinary coil winding set in slots. The other, a squirrel-cage winding.

Figure 173 shows you the rotor construction. Notice the slots ready to receive the regular winding. Also notice the copper bars of the squirrel cage.

This motor has the regular commutator and shorted brushes. Thus, it gets its initial start as a repulsion motor. Once under way, the squirrel-cage winding takes over and the motor runs as an induction job.

THE UNIVERSAL MOTOR

Want to make your buddy's eyes pop out? Then just hook a fan with a D.C. MOTOR onto an A.C. LINE. While he's making a beeline for the door you can sit back and enjoy the cooling breezes. All you have to do is be sure that (1) the d.c. motor has the same voltage rating as the a.c. line, and (2) the motor is a SERIES MOTOR.

When your buddy gets back you can straighten him out on a few things. First of all, you'll tell him that a series motor will work on both d.c. and a.c. That's because the armature is in series with the field coils. Armature and field carry the same current. Sure, the a.c. will reverse its direction in the field coils and change their polarity, but at the same time it is reversing the polarity of the armature coils. The result is a torque always in the same direction. And the armature rolls merrily on its way.

You want to be sure and point out to your buddy that the motor you used would have worked better on direct current. You can prove this by letting him touch the motor housing. It will be quite hot. The fan will also be rotating slower than its normal speed rating.

After all, the fan was designed to work on direct current. Probably, only the field pole tips were laminated. The changing field in the solid parts of the field structure is producing a lot of heat. And the field coils themselves are wound with a large number of turns of wire. This presents a high resistance to

alternating current. As a result the current and magnetic field strength are reduced. It would have been better to use a series motor designed for both alternating current and direct current. This type of motor is called a UNIVERSAL MOTOR.

Construction

Universal motors are usually small in size. The entire field structure is laminated. Figure 174 shows a typical field core. Notice that the field poles and core are made from one stamping. When all the stampings are riveted together they form the laminated field core.

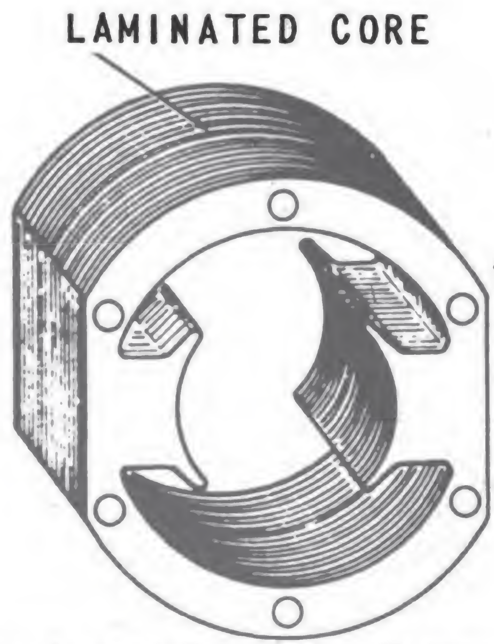


Figure 174.—Field core of a universal motor.

The field coils are prewound, taped, and then formed to fit the contour of the core. Figure 175 shows you the appearance of the field coils for a two-pole universal motor. You can also see the three methods used to hold the field coils on the field poles. A pin through the core is one method. In another, the coils are secured with metal clamps. The third method uses fiber wedges.

The brushes of the smaller universal motors can be removed through openings in the end plate. Each brush is mounted in a

brush holder secured to the end plate. This construction is shown in figure 176.

There's nothing out of the ordinary about the armature and commutator construction. You'll just find them smaller

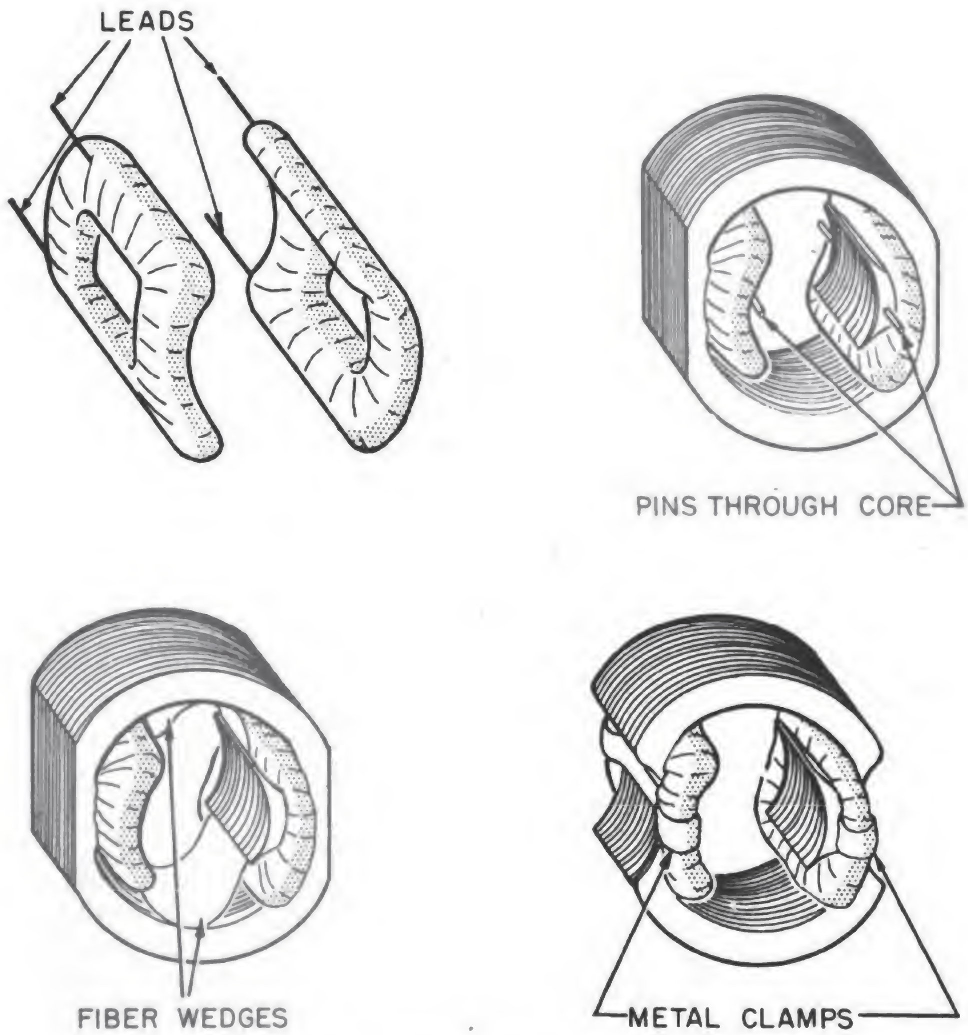


Figure 175.—Field coils and methods of securing.

in size. All of the parts, including the armature, of a universal motor are laid out for your inspection in figure 177.

CONTROLLING THE A.C. MOTOR

Alternating current motors power everything from small portable drills to giant hoists and cranes. The same pattern

is always followed. Electrical energy enters the motor and causes the rotor and shaft to rotate. This mechanical energy is transferred to the equipment by gear or pulley.

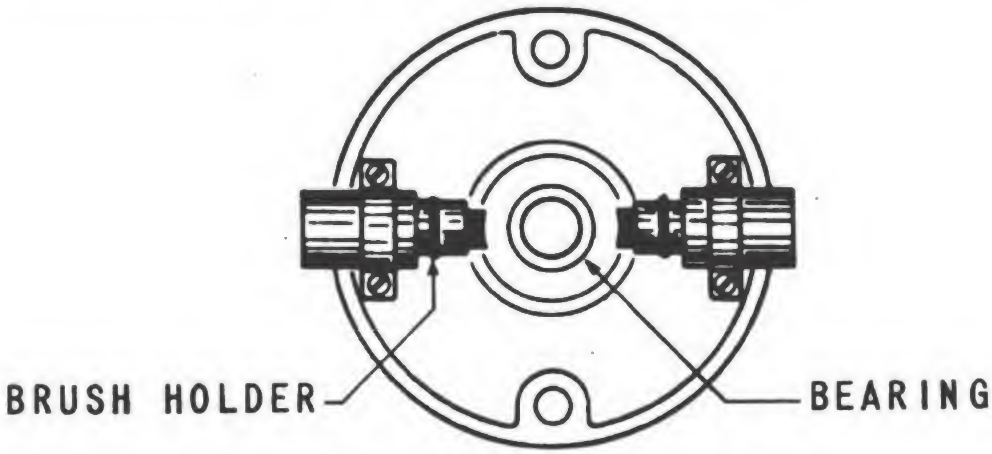


Figure 176.—Brush holders secured to end plate.

To control the equipment, you control the motor. The most sensible place is at the electrical input end. By closing and opening the line you can START and STOP the motor.

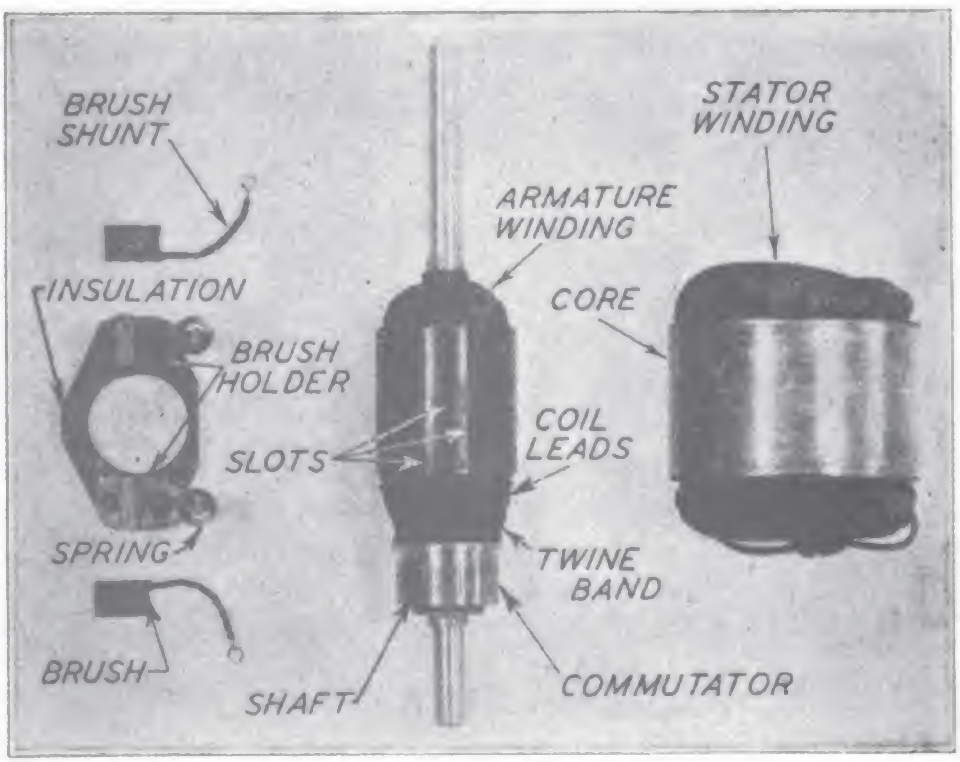


Figure 177.—Unassembled universal motor

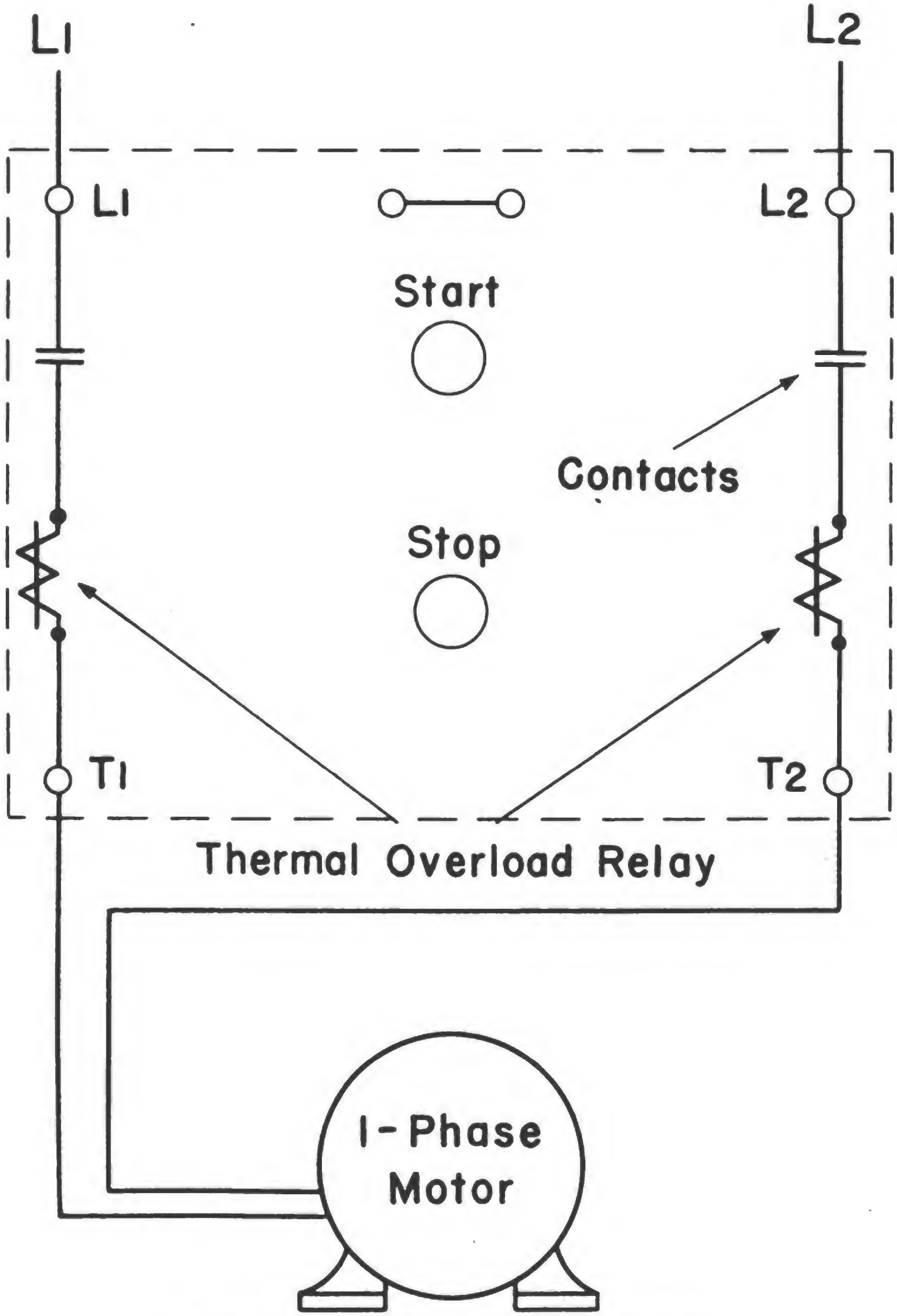


Figure 178.—Single-phase across-the-line-starter.

Controllers for a.c. motors fall into two main classes. One is termed an ACROSS-THE-LINE-STARTER, the other a REDUCED-VOLTAGE STARTER.

Across-the-line-starters (Manual Control)

Small a.c. motors of less than 1 horsepower don't draw too high a starting current. As a result, these motors may be started by placing them DIRECTLY ACROSS the line. These types of starters are called across-the-line-starters.

Most across-the-line-starters have all of their working parts enclosed in a metal box. This prevents you from touching a live circuit. The switch lever or pushbuttons protrude through the front cover of the box. Usually, each switch will have a wiring diagram of its circuit pasted on the inside surface of the front cover. Such a diagram is shown in figure 178. This happens to be a switch for a single-phase motor.

Pressing the START button will cause a toggle mechanism to flip two contact buttons together. The contacts are located in each leg of the line. They are represented by the symbols shown just below terminal L_1 and L_2.

The toggle mechanism holds the contacts together after you remove your finger from the start button. The motor is now connected directly across the line and will operate. To stop the motor, just press the STOP button. This causes the toggle mechanism to flip back, opening the contacts. The motor will stop.

Notice that zig-zag symbol just above the terminal marked T_2. It indicates that a fuse is inserted at that point. This fuse is used to protect the motor against excessive currents while the motor is operating. It is called a THERMAL OVERLOAD RELAY.

The overload relay works by action of heat given off by the current. Either a bimetallic strip or low melting alloy is used. In either case the end result is the same. Excessive current causes high heat. The heat causes the overload relay to work, disconnecting the starting contacts. Once the heat is removed the relay will return to normal. To restart the motor it is necessary to push in the start button again. In some cases a RESET button is provided.

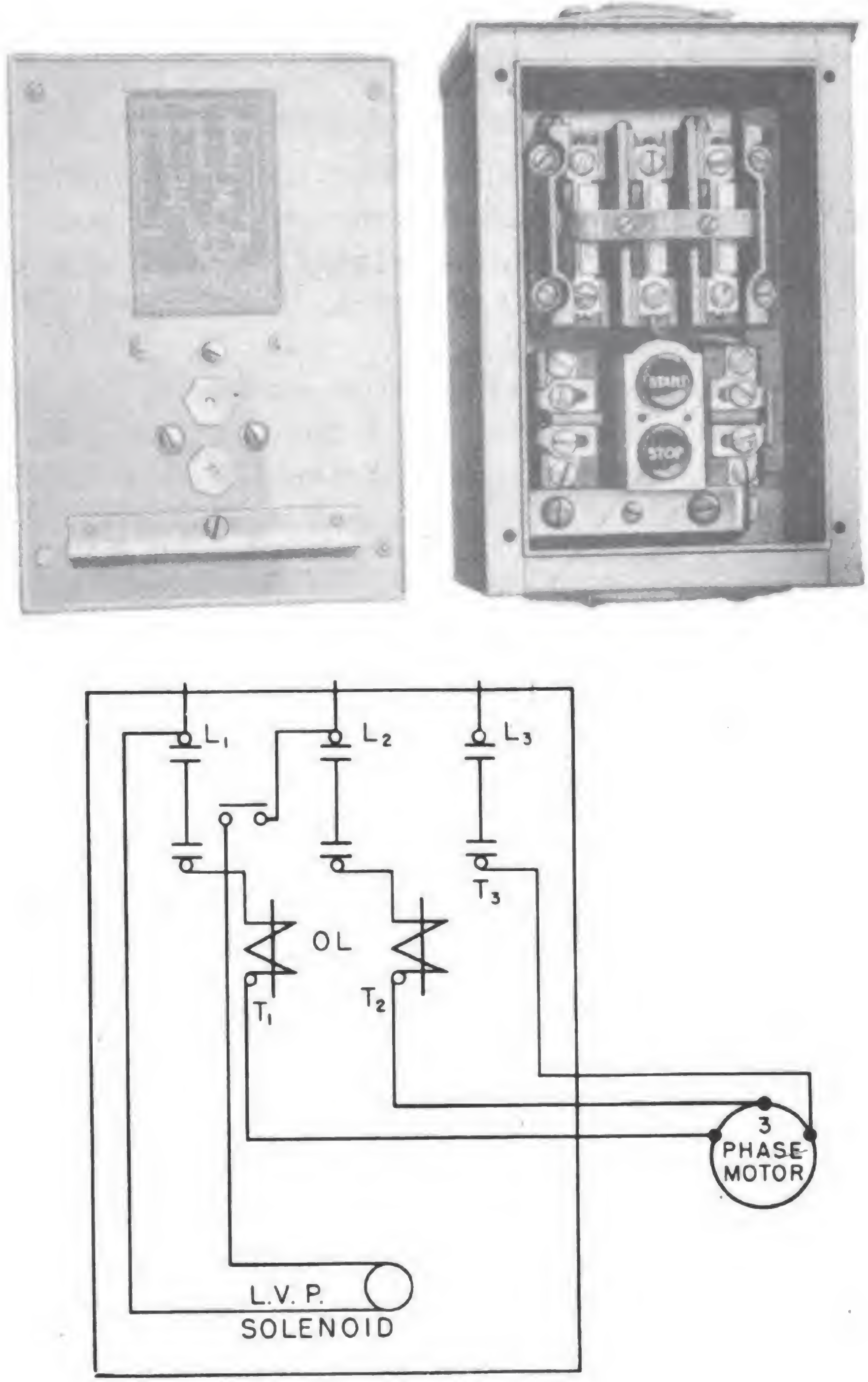


Figure 179.—Three-phase across-the-line-starter.

Across-the-line-starters are used for three-phase motors, too. Since three wires are used you'll find three contact switches, instead of two. And there will be two thermal relays. Figure 179 shows you the actual switch with the front cover removed. The wiring diagram is also shown.

Across-the-line-starters (Magnetic Control)

The starters discussed above were MANUALLY OPERATED. There was a direct mechanical contact between start and stop button and the line contacts. In the MAGNETIC across-the-line-starter, electricity does the work. This allows you to control the motor from a distance.

The magnetic across-the-line-starter consists of two parts. One is the start-stop station, and the other the magnetic starter. The start-stop station contains the start and stop buttons. A picture of this can be seen in figure 180. Wires

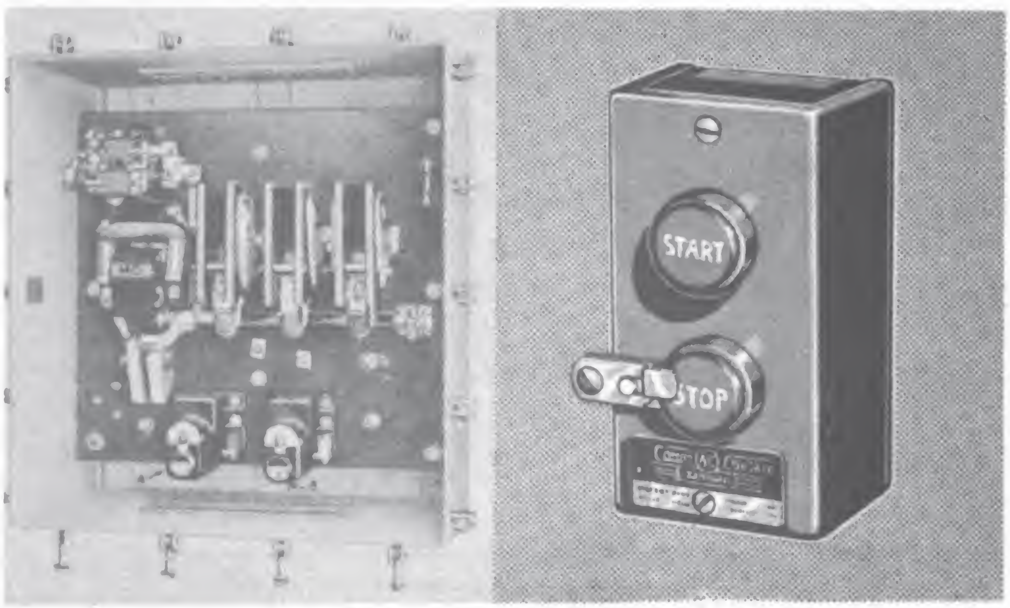


Figure 180.—Magnetic across-the-line-starter.

connect the start-stop station to the magnetic starter which is located near the motor. The starter can also be seen in figure 180.

To understand how this starter works look at figure 181. It is a wiring diagram of the magnetic across-the-line-starter. The start-stop buttons aren't a toggle switch affair. They are

called MOMENTARY contacts. Notice that in its normal position, the start button is open. The stop button, on the other hand, is normally closed. Each is held in their normal position by a spring.

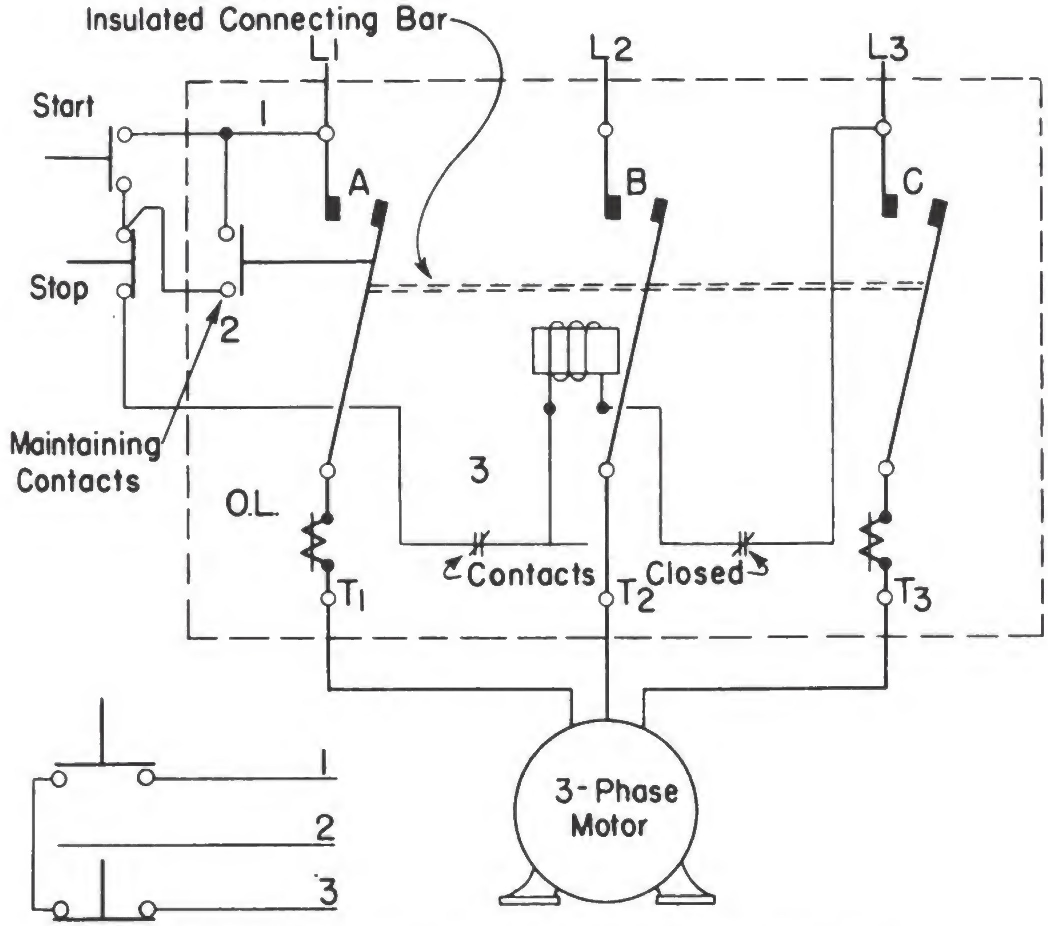


Figure 181.—Wiring diagram of magnetic across-the-line-starter.

Now take a look at the magnetic starter. It contains a relay. The relay consists of the electromagnetic coil and three iron contact BARS (*ABC*). The three bars are held together by a rigid insulated support. When one bar moves, the other two move with it. All the bars are in the open position before the relay is energized. Notice that holding contact, connected to relay bar *A*. When the bar moves, the holding contact moves with it.

The operation of the switch is as follows:

1. Pushing the start button completes the electromagnet circuit through the stop switch.

2. When the electromagnet is energized it pulls the three relay bars into contact with the main line.

3. The motor is now connected directly across the line. At the same time, the contact on relay bar *A* completes its circuit to the electromagnet.

4. The start button may be released. The holding contact will keep the electromagnet energized.

To stop the motor it is only necessary to push the stop button. This will open the electromagnet circuit. The relay bars will return to their original position, opening the line circuit.

Notice the overload relays. There is one in each outside leg of the three-wire line. The relay contacts are placed in series with the electromagnet. An overload causes the relay to work, opening the contacts. The electromagnet is deenergized and the motor stops.

This type of starter serves two purposes. Having metal contact bars of considerable area, it allows the heat to be dissipated and prevents pitting of contact points. Also, the make and break contact action is performed far quicker than would be possible by hand. This speed tends to reduce the arcing caused by large starting currents.

Reduced-Voltage Starters

When a large a.c. motor is first turned on, it draws a great deal of current. The motor itself is designed to handle the starting current. It's the other a.c. motors hooked to the same line which suffer. A large current drain will cause the line voltage to take a nose dive. The other motors might stop operating.

Reducing starting current is as easy as reducing the input voltage. Reducing the input voltage is as simple as placing a dropping resistor in the input line. Figure 182 shows you how this is accomplished.

The starter panel contains a resistance strip, a movable arm, and a holding coil. The resistance strip is tapped at different points. The tap leads are connected to copper buttons.

One end of the resistance is wired to one end of the stator coil of the motor.

The movable arm is pivoted at one end. The other end of the arm slides over the resistance taps. A spring maintains a tension on the arm at all times. The arm is connected to one side of the main line. The other side of the line is connected

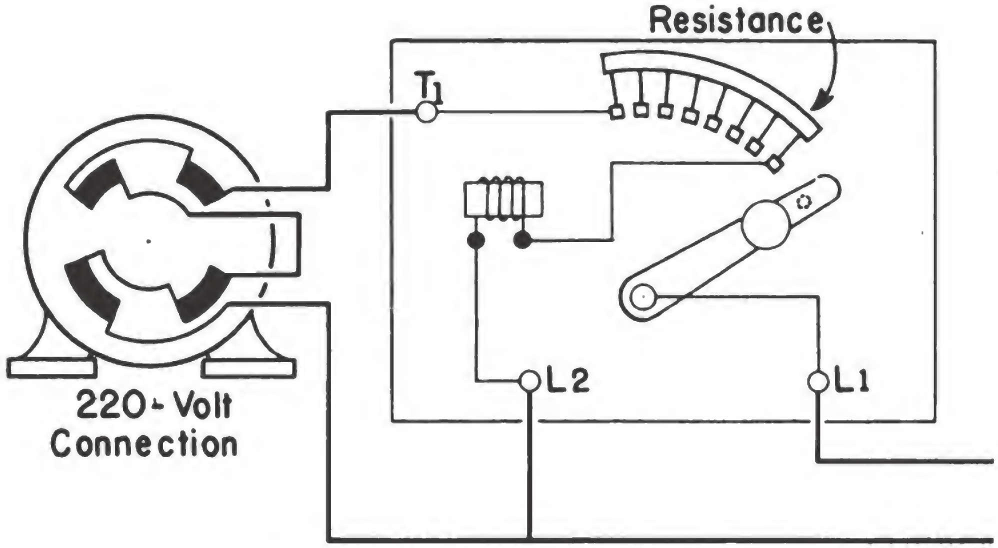


Figure 182.—Manual resistance starter.

directly to the stator coil of the motor. The holding coil is connected across the line.

To start the motor, you move the arm to the first contact. This places the full resistance in series with the stator field coils. The starting current is kept low. As the motor begins to gain speed, you slowly move the arm up to the last contact. At this point the motor is directly across the line and is working at its normal rating.

The holding coil acts as an electromagnet. Any magnetic material that is brought close to the coil will be attracted to the coil core. There is a soft iron shoe on the movable arm. When the arm is at its full position, the soft iron shoe will stick to the holding coil. This holds the arm at the run position.

Don't forget that the arm is under spring tension. This tension is always trying to pull the arm back to the off position. As long as the holding coil is being energized, the arm will stay

put. If the line voltage fails, the holding coil is deenergized and the arm springs back to the off position. The motor stops running. To start the motor it is necessary to reset the resistance arm.

Resistance starters may be used on three-phase motors, too. Two variable resistors must be used. The set-up is shown in figure 183. The two arms are connected together. The resistance in each leg will be reduced the same amount.

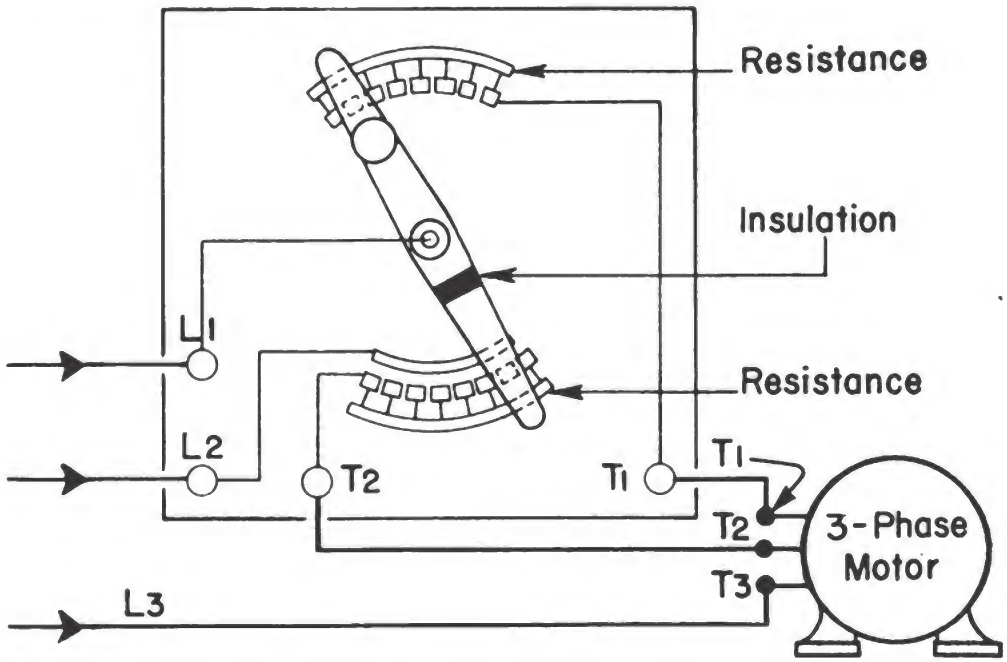


Figure 183.—Resistance starter for three-phase motor.

MORE ABOUT STARTERS

The resistance starters described above are the MANUAL TYPE. There are MAGNETIC ones, too. Relays are used to insert fixed resistances into the motor input. After a fixed time, the relays open, removing the resistances.

When a resistance is used to reduce the starting current, a large amount of energy escapes as heat. Some starters employ a transformer to reduce the input voltage. Using a transformer is a natural way to change a.c. voltage. The heat losses are kept to a minimum. Transformer starters may also be of the manual or magnetic type.

SUMMARY

In an a.c. motor, current is introduced into the rotor by induction.

A squirrel-cage rotor for large motors consists of copper bars connected at each end to copper end rings. In small motors the squirrel-cage assembly is made of aluminum and cast as a complete unit.

A three-phase motor has three sets of stator windings. A three-phase voltage impressed across the stator produces a rotating field. The squirrel-cage rotor follows the field.

Single-phase motors must use starting devices.

A split-phase motor and capacitor motor use an extra stator winding as a starting device. A centrifugal switch usually cuts the extra winding out.

A repulsion motor uses short-circuited brushes and a commutator as the starting and running device.

A repulsion-start, induction-run motor starts as a repulsion motor and runs as an induction motor. A short-circuiting necklace is used for the change-over. In some motors the brushes are lifted away from the commutator.

A repulsion-induction motor has a squirrel-cage winding in addition to the regular winding. No short-circuiting necklace is required.

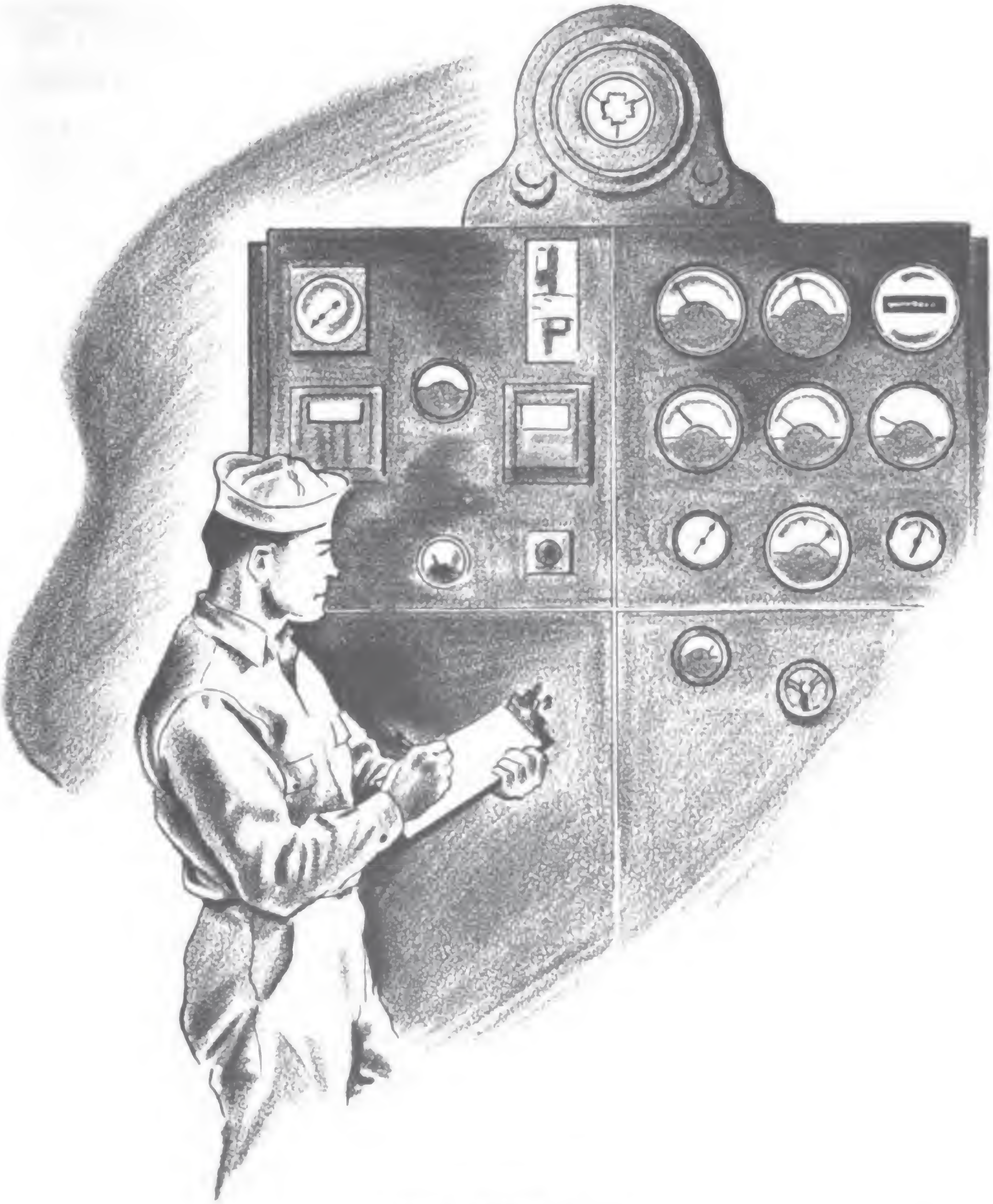
The universal motor may be used on both alternating and direct current.

Motor controllers are classified as across-the-line-starters and reduced voltage starters. Each type may be further classified into manual starters and magnetic starters.

QUIZ

1. The rotor of an a.c. motor can be compared to what part of a transformer?
2. Is the current which flows in the a. c. motor rotor supplied from the external circuit?
3. In the three-phase motor, does the rotor lead or follow the rotating magnetic field?
4. What is the simplest and most commonly used rotor in a.c. motors?

5. Why is insulation unnecessary between the copper bars and the steel core of a squirrel-cage rotor?
6. At what approximate percentage of full speed does the centrifugal switch disconnect the starting winding from the line?
7. What type of motor uses a condenser to "split" the single-phase current?
8. What force is utilized to disconnect the starting winding?
9. What is the common a.c.-d.c. motor called?
10. Name two main classes of a.c. motor controllers.
11. Name two types of switches used to start motors under full load.
12. Why is it necessary to reduce the input voltage when starting large motors?



CHAPTER 7

ADVANCED BASE ELECTRIC GENERATING STATIONS

FACTS FIRST

Ever watch a movie of an invasion? Action, thrills, perfect timing—it's all there, and more to boot. First, the preinvasion barrage with the battle wagons pouring in enough high explos-

ives to wipe a city off the map. Then it's dive, strafe, bomb, hit, and run, as the carrier planes add their special touch.

Get a good grip on your seat: here comes the invasion force! Hundreds of landing craft approach the beach and grind to a halt on the shore. The ramps come down and out pour the combat troops. It's touch-and-go for awhile, but the long-awaited words finally come through: BEACHHEAD SECURED! An exciting picture with an exciting ending—or is it the end?

Hold it. Stick around awhile. There's more to come. You know that securing the beachhead is just one phase of the operation. Those troops must keep pressing forward. To do the job right they need a lot of support. That support can be boiled down to two things—MEN and SUPPLIES.

Until they're needed, the men must be quartered and fed. The supplies must be stored. All this calls for a jumping-off point. It's known as an ADVANCED base.

Talk about advanced bases and you talk about the Seabees. They build them. Airstrips, operational headquarters, communication shack, and dispensary get top priority. Then comes the mess hall and finally, the living quarters. And they all need something in common—ELECTRIC POWER.

This is where you come in. Electric power is your business. You're the fellow who will operate and maintain the generators to produce that electric power.

PACKAGED POWER

Electric generators for advanced bases come in neat packages: the small jobs in crates, the larger ones in completely enclosed metal housings. The prime mover (gas or Diesel) and the generator (a.c. or d.c.) will be mounted as a complete unit. Auxiliary equipment, such as tool kit, fuel tank, battery, and electrolyte is also included.

You'll find these generators portable and rugged. They've got to be in order to meet the needs of an advanced base. The airstrip, headquarters, and communication shack need power—and they need it in a hurry. It's as easy as spotting a generator at each of those points. Sure, they're out in the open,

but they are built to take it. Figure 184 gives you a preview of one of these packaged jobs. It uses a Diesel engine for its prime mover.

Figure 184.—Packaged power.

NEED FOR CENTRAL POWER

Pin-pointing a generator unit at every location requiring power is O.K.—up to a certain point. As the advanced base grows, however, power supply becomes a problem. Each power plant is going to require an operator. That's disadvantage number one. And there's always the possibility of a breakdown. Until the generator is repaired, no power is available. That's disadvantage number two. Even though the generators are built for outside service, they can only take so much. Rain and snow can do a lot of damage to a generator unit. That's disadvantage number three.

All these disadvantages are overcome with a CENTRAL POWER STATION. The electric power for each section of the advanced

base is generated at one location. Two or three large generator units will replace the ones scattered over the section area.

A central spot will need just one operator at any one time. That's advantage number one. There is always a steady supply of power. If a generator breaks down, the flip of a switch brings an emergency unit onto the line. That's advantage number two. And with the generators placed in a building, the weather becomes just something to talk about. That's advantage number three.

Check figure 185 for a picture of a typical advanced base power station.

Figure 185.—Advanced base power station.

DIESEL-DRIVEN GENERATOR SETS

Next chance you get, take a look at some of the Diesel-driven generators around the base. Dollars to doughnuts, you'll find at least two or three different makes. International, General Motors, Witte, and Caterpillar are just a few. And

each manufacturer has his own idea on how to start the Diesel engine and the type of fuel-injection system to use.

THE BASIC PARTS, however, can't be changed. Every advanced-base Diesel-driven generator set will have a DIESEL ENGINE. Directly coupled to the engine's crankshaft will be the GENERATOR. Meters and switches to control both the Diesel engine and the generator are mounted on a CONTROL PANEL (switchboard). These three basic parts are shown on the 30 kw Buda model in figure 186.

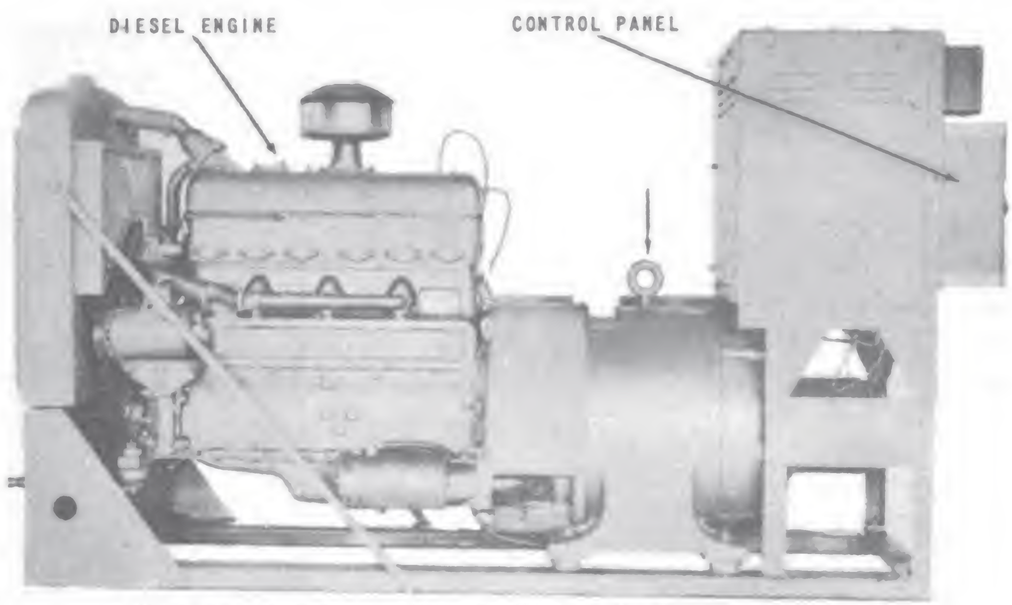


Figure 186.—Basic parts of a Diesel-driven generator set.

HOW THE DIESEL ENGINE WORKS

Diesel engines work when heat energy is changed to mechanical energy. Heat is developed when a mixture of compressed fuel and air burns INSIDE a cylinder. Expanding gases are formed. The gases exert a pressure on a PISTON which is connected to a CRANKSHAFT by means of a CONNECTING ROD. The straight line movement of the piston is changed to a rotating movement of the crankshaft.

Diesel engines do not use spark plugs to ignite the air-fuel mixture in the cylinder. Don't say it can't be done until you look at figure 187. It shows a cutaway view of a cylinder used in a Diesel engine.

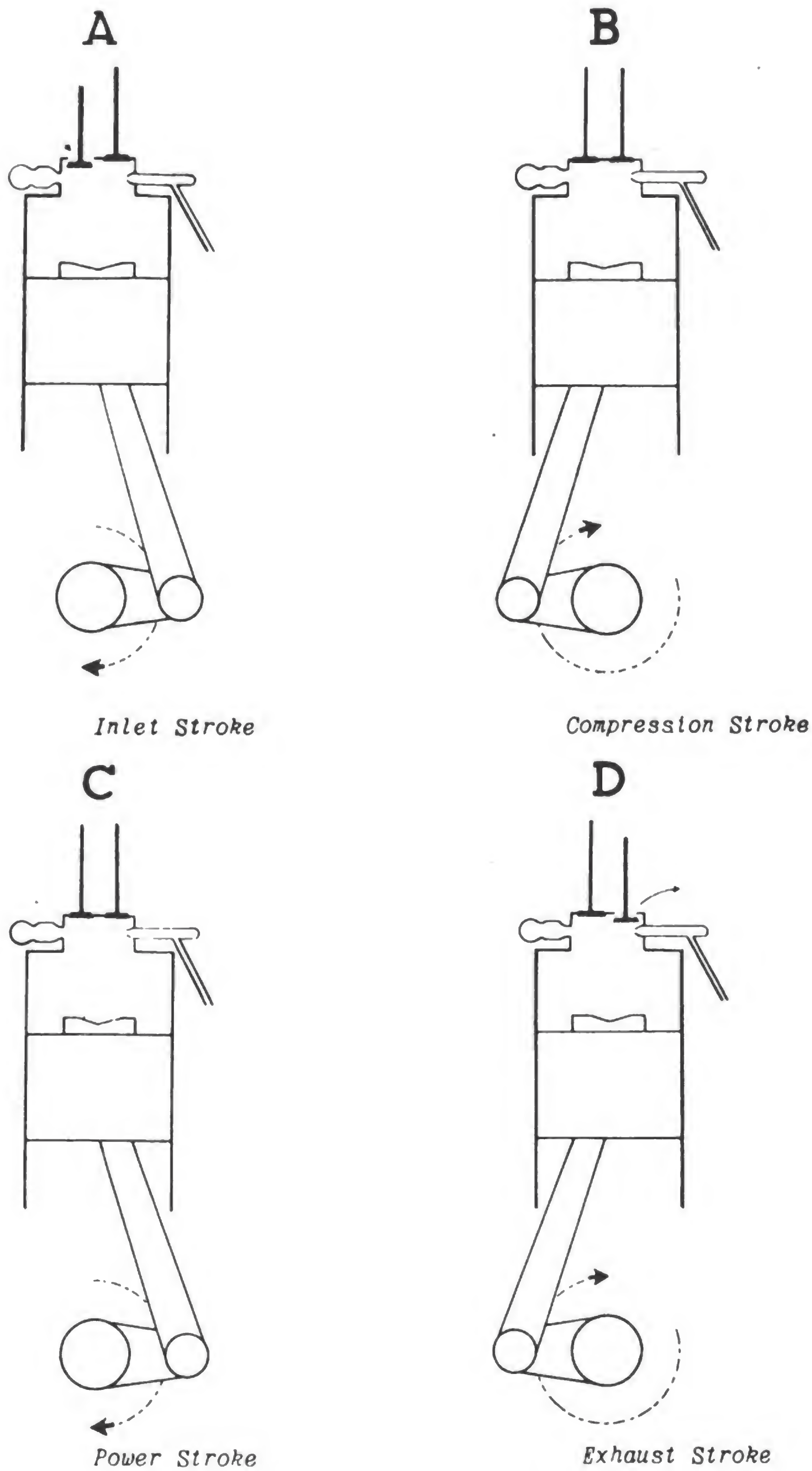


Figure 187.—Four-stroke cycle.

Start with view *A*. The crankshaft is forced to turn in the direction of the arrow. This pulls the piston down. The inlet valve opens and PURE air is sucked into the cylinder. This is called the INLET STROKE.

Now look at view *B*. This piston is moving in an upward direction. The inlet valve is closed. As the piston moves upward it sandwiches the air into a smaller and smaller space. The air tries to resist this compression. As a result, its temperature rises to about 1000° F. Fuel oil is sprayed into the compressed air space just as the piston reaches the top of its stroke. THE HEAT OF THE COMPRESSED AIR WILL IGNITE THE FUEL. This is called the COMPRESSION STROKE.

Change over to view *C*. The gases formed by the ignition of the fuel are pushing the piston down. Heat energy is changed to mechanical energy. The crankshaft is forced to rotate. This is called the POWER STROKE.

End with view *D*. The piston has completed its power stroke. As it starts upward, the exhaust valve opens. The burned gases are pushed out of the cylinder. This is called the EXHAUST STROKE. On its downward stroke, the piston sucks in fresh air and the whole cycle begins again.

Of course, there is more than one cylinder in a Diesel engine. The pistons are arranged on the crankshaft in a definite pattern. Thus, at any instant, each piston is in some phase of the four-stroke cycle. The result is a smooth delivery of power to the crankshaft.

You'll find that some Diesel engines use a TWO-STROKE CYCLE. The compression stroke and exhaust stroke are eliminated. A blower fan is used to force fresh air in and burned gases out of the cylinder.

DIESEL-ENGINE AIR SYSTEM

You couldn't last without air and neither can the Diesel engine. The Diesel uses the air in its cylinders—you use it in your lungs. Every time you inhale you bring in gobs of fresh air to your lungs. The same thing happens to the Diesel on the inlet stroke. When you exhale you push out all the bad air. The Diesel does the same thing on the exhaust stroke.

Dust particles in the air don't do your lungs any good. The small hairs in your nose strain out most of the dirt. A Diesel engine needs clean air too. Grit and dust are removed by an AIR CLEANER.

The air cleaner is mounted on the top of the engine block as shown in figure 188. It is connected directly to the inlet or intake manifold which supplies air to all the cylinders.

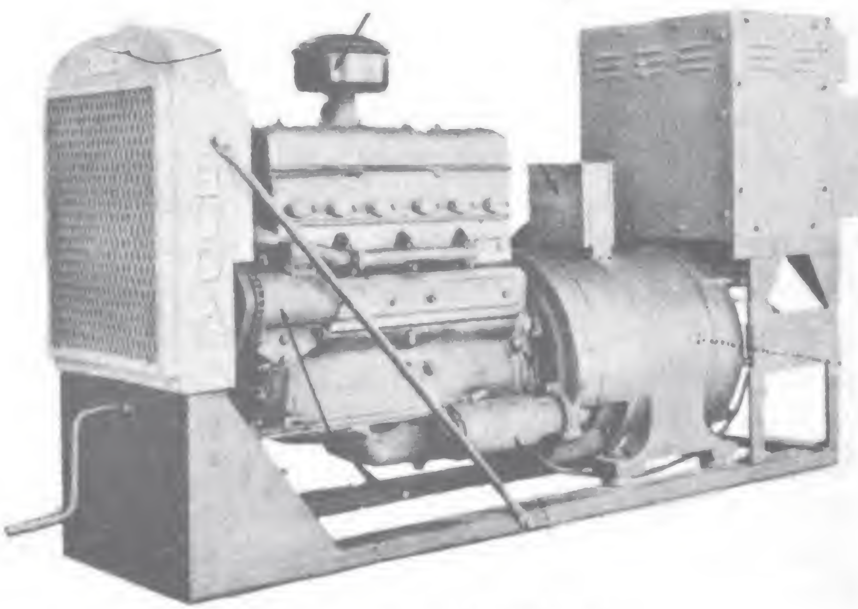


Figure 188.—Location of air cleaner.

Most air cleaners are of the oil-bath type. The cross-sectional view in figure 189 will help you understand its construction and action. The bottom half of the cleaner contains oil, the top half, a filter of metal wool. The air first passes over the surface of the oil. Most of the dirt is trapped at this point. The air continues up through the metal wool which filters out the remaining dust. Pure air passes down the center tube to the inlet manifold.

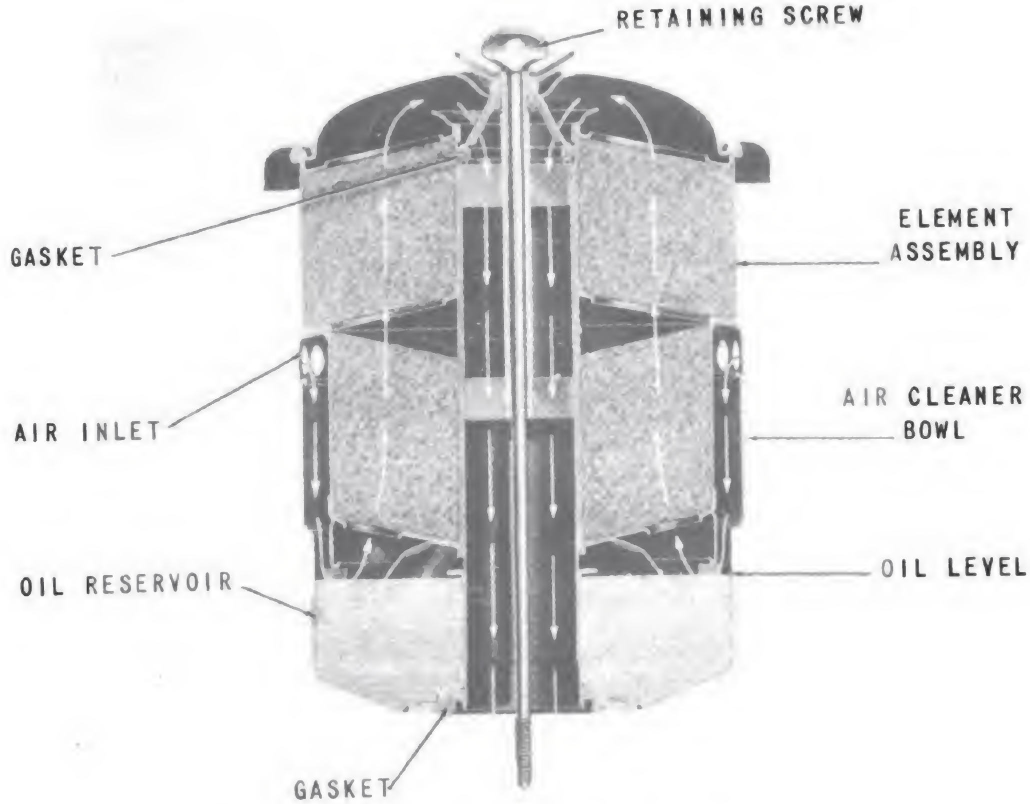


Figure 189.—Air-cleaner construction and action.

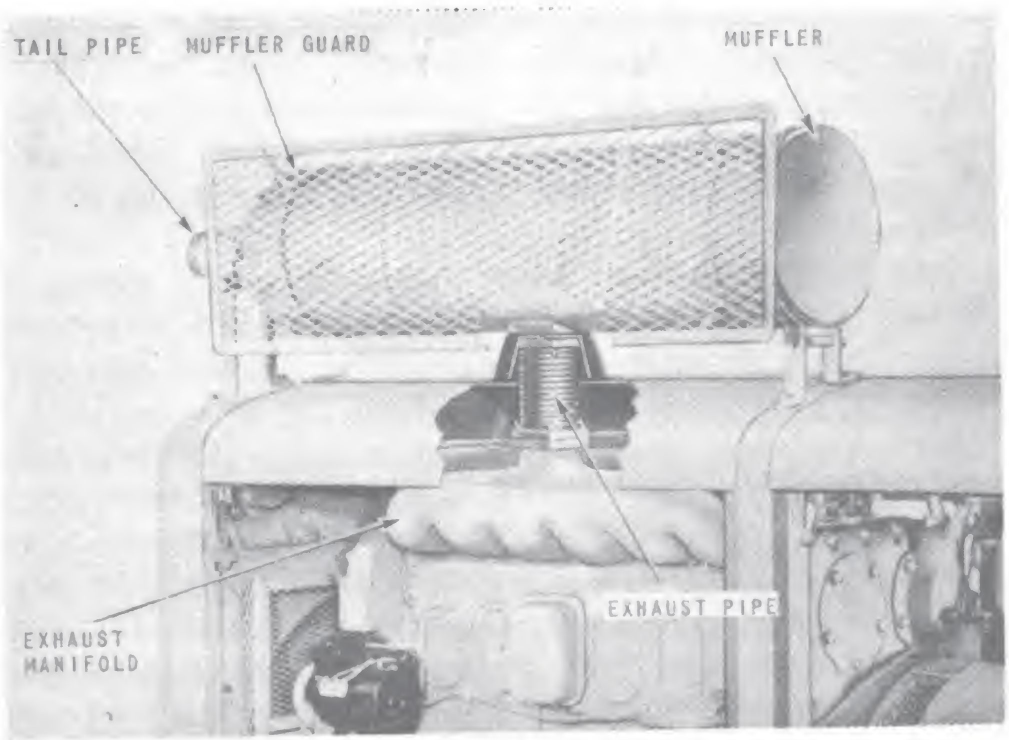


Figure 190.—Exhaust system.

On the exhaust stroke, burned gases are forced out of the engine through the EXHAUST SYSTEM. The gases flow into an EXHAUST MANIFOLD which is connected to all the cylinders. The gases leave the manifold by way of a flexible EXHAUST PIPE and enter a MUFFLER. The muffler helps to silence the exhaust noise of the Diesel engine. The gases leave the muffler through the TAIL PIPE. Figure 190 shows the location of the exhaust system.

POINTERS ON THE AIR SYSTEM

An air cleaner can remove just so much dirt. To operate efficiently, it must be cleaned out regularly. The metal wool elements are washed. The dirty oil is drained and the sludge removed. New oil is then added.

The manufacturer's instruction book tells you how often this operation must be performed. Detailed diagrams show how to take the air cleaner apart. Be sure that the new oil you add is the same type recommended by the manufacturer.

Notice that the tail pipe in figure 190 is threaded at the exit end. This allows you to attach additional tail pipe. If the Diesel is located in a building, the tail pipe is extended through the wall. Thus, the poisonous fumes in the exhaust escape into the open air. It's a good idea to rig up the tail pipe so that it slopes downward from the muffler. Then, any moisture which forms in the pipe will run out the end of the pipe instead of back into the engine.

Stay away from the exhaust system when the engine is running. Any part of the exhaust is hot enough to give you a severe burn. In some engines a muffler guard (figure 190) protects the operator.

Sure as shooting, someone will get burned. It's up to you to apply first aid. THE FIRST THING TO DO IN THE CASE OF HEAT BURNS IS TO PROTECT THE FLESH FROM CONTACT WITH THE AIR. If a special burn ointment is available, use it. But don't take time to run out and get some from the dispensary. Oil, soft grease, or vaseline will serve the same purpose. Just be sure not to use an antiseptic or powder. And don't dress the burn. Let the doctor take care of that.

DIESEL-ENGINE COOLING SYSTEM

Internal-combustion engines run when heat energy is changed to mechanical energy. The heat energy is developed from the combustion of compressed fuel and air in the cylinders. It's a sad but true fact that not all of the heat energy can be used. There's just too much of it for the engine to handle. The pistons and the cylinder walls would become just a mass of fused metal.

Only about 25 percent of the heat energy is turned into useful power. Approximately 45 percent is carried out by the exhaust. The rest is removed by the lubricating and cooling systems of the engine.

Let's talk about the cooling system first. Each cylinder is surrounded by passages through which water is forced to circulate. The heat formed in the cylinders passes through the cylinder walls and is carried off by the water.

The same water is used over and over again to keep the engine at the proper operating temperature. The RADIATOR, COOLING FAN, and WATER PUMP do the trick. Hot water enters at the top of the radiator and flows down through large numbers of small tubes. The tubes are attached to radiating fins. Tubes and radiating fins make up the radiator core.

The fan, which is driven by the crankshaft, pulls cool air through the radiator core. Heat is transferred from the water to the air. The cooled water then begins its trip back through the water jackets surrounding the cylinders. Continuous circulation of the water is maintained by the water pump.

A typical cooling system is shown in figure 191. Here you can see the exact path the water takes. Notice the bypass pipe which detours the water around the radiator. Any water which passes through the bypass is not cooled. An automatic valve, called a THERMOSTAT, controls this passageway.

Here's the reason for the bypass. Diesel engines operate best when the water in the cooling system is approximately 180° F. When the engine is first started, the water is far below this temperature. The thermostat automatically closes the passageway leading to the radiator. At the same time it opens the bypass route. The water has a chance to heat rapidly. Once the water reaches its proper temperature, the thermostat

opens the radiator pipe and closes the bypass, and the water is forced through the radiator.

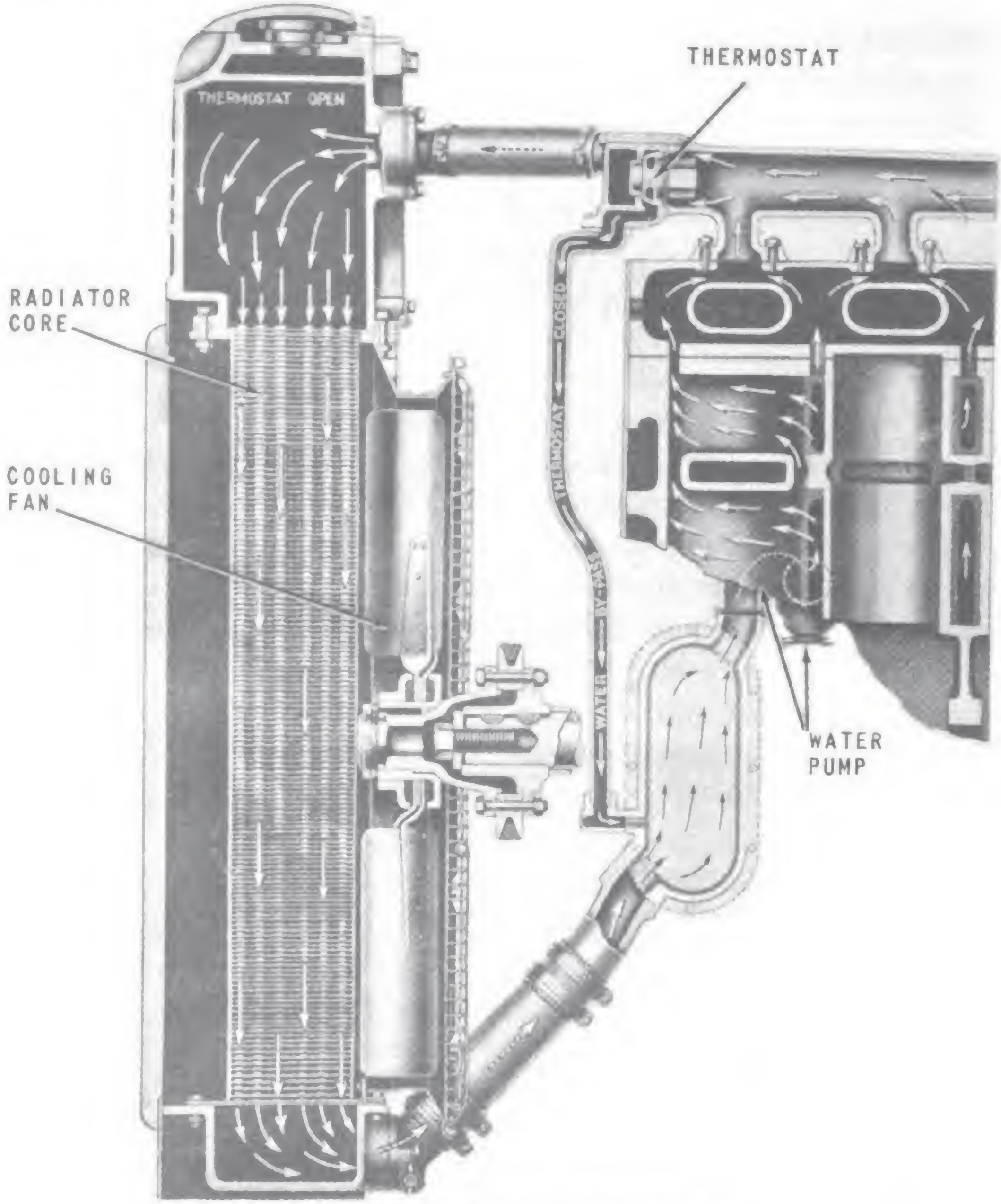


Figure 191.—Typical cooling system.

Pointers on the Cooling System

The water in the cooling system will gradually evaporate. It's your job to replace the water lost in this manner. Water is added to the system through an opening at the top of the radiator. BE SURE that YOU USE SOFT, CLEAN WATER. Hard

water, such as sea water, which contains minerals, will cause deposits to form in the cooling system. This reduces the efficiency of the system, and will shorten the life of the engine.

The radiator core should also be inspected regularly. Dirt, grease, and insects are sucked in with the air. They lodge in the small openings of the core. If allowed to accumulate, they will prevent the flow of air through the core. An overheated engine is the result. A strong blast of air is the best remedy for a clogged radiator core.

DIESEL-ENGINE LUBRICATING SYSTEM

If you should put a window in a Diesel engine, you would see a lot of action. Pistons SLIDING inside the cylinders, connecting rods TURNING the crankshaft, idler gear MESHING with the crankshaft gear—all metal-to-metal contact. That means FRICTION, and friction means HEAT. Enough heat, in fact, would be produced to melt the parts in a matter of seconds—unless a LUBRICATING OIL is used.

The lubricating oil will reduce the friction to a safe point—but it won't get rid of it completely. As a result, small particles of metal will be torn from the moving parts. Thus, the lubricating oil has another job—removing the particles to a place where they'll do no harm.

To remove the heat of friction and the metal particles, the oil must be in continuous circulation. That's the job of the lubricating system. Figure 192 shows a typical set-up. The lubricating oil is kept in a reservoir or OIL PAN which forms the lower part of the engine. The oil is kept circulating through the engine under pressure of an OIL PUMP. The oil leaves the oil pan by way of the OIL-PUMP INTAKE. It travels through an OIL STRAINER where large particles are removed. The next stop is the OIL COOLER where the water from the cooling system removes most of the heat from the oil. The clean, cool oil then circulates through the internal working parts of the engine. The oil, after doing its job in the engine, returns to the oil pan. Part of it is bypassed through an OIL FILTER. This is the point where sludge, dirt, and fine metal particles are removed.

Figure 192 has probably brought a few "whys" into your mind. Number one, why is it necessary to have a bypass route around the oil strainer? The answer is that the bypass insures a flow of oil to the engine if the oil strainer gets clogged. Number

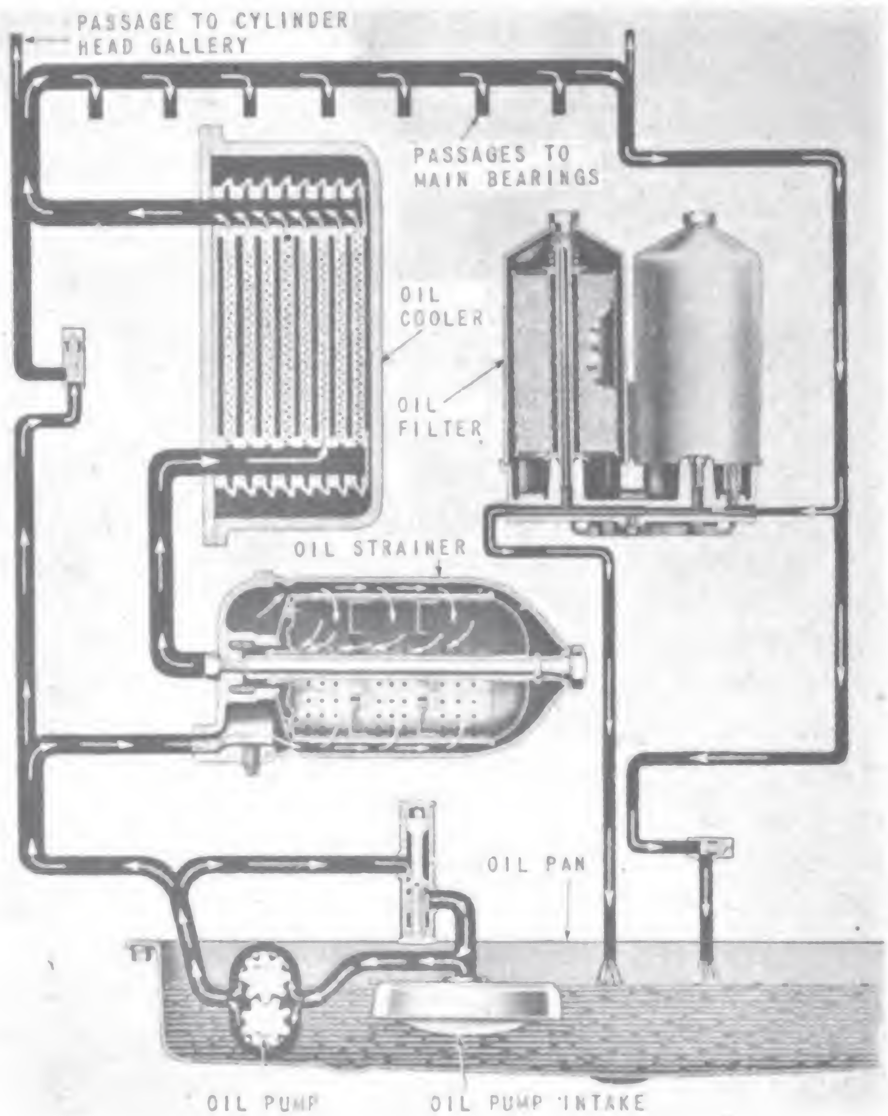


Figure 192.—Schematic lubrication diagram.

two, why does just a part of the oil travel through the oil filter at any one time? The answer is that this allows a continuous oil pressure to be maintained. Since the oil is circulating, all of it will pass through the filter over a period of time.

Pointers on the Lubricating System

It's your job to see that there is always enough oil in the oil

pan. And you don't just guess at it. An OIL-LEVEL GAGE, or dip stick, is provided for exact measurements. The dip stick fits into a hole in the engine block with its lower end dunked in the oil reservoir. Figure 193 shows a dip stick removed from the engine. Notice that the oil level comes only to the LOW mark. In this case you would add enough oil to bring the level to the FULL mark. A FILLER PIPE is provided as a means of adding the oil to the engine.

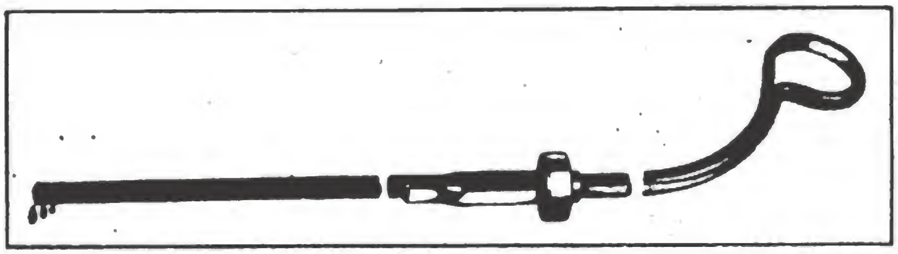


Figure 193.—Oil-level gage.

Never take an oil-level reading of an engine which has been stopped for some time. Oil, which normally should be up in the engine parts, will have had time to drain back into the crankcase. A false high reading will result. The best method, if the engine has been idle, is to start it and run it for about ten minutes. Then stop the engine, allow five minutes for the oil to settle, and check the oil level.

The oil strainers and filters will last just so long. Then they get clogged with sludge and dirt. When this happens, the oil will turn a dirty color and must be changed. At the same time the filters should be cleaned and replaced. Your manufacturer's instruction book will tell you exactly when and how. Be sure to use the grade of oil that is recommended by the manufacturer.

DIESEL-ENGINE FUEL SYSTEM

You have the air, cooling, and lubricating system down pat. Now all that's needed is fuel for combustion in the cylinders. By the way, you want to remember that FUEL OIL, and not gasoline, is used to run the Diesel engine.

The fuel oil must get from the fuel tank to the cylinders. The FUEL SYSTEM directs it there. Figure 194 shows how it's done. A transfer pump draws the fuel from the fuel tank through a PRIMARY FILTER. The primary filter strains out any large particles of dirt. The fuel then travels over to the SECONDARY FILTER which removes the remaining small particles. Sludge and water are also trapped here.

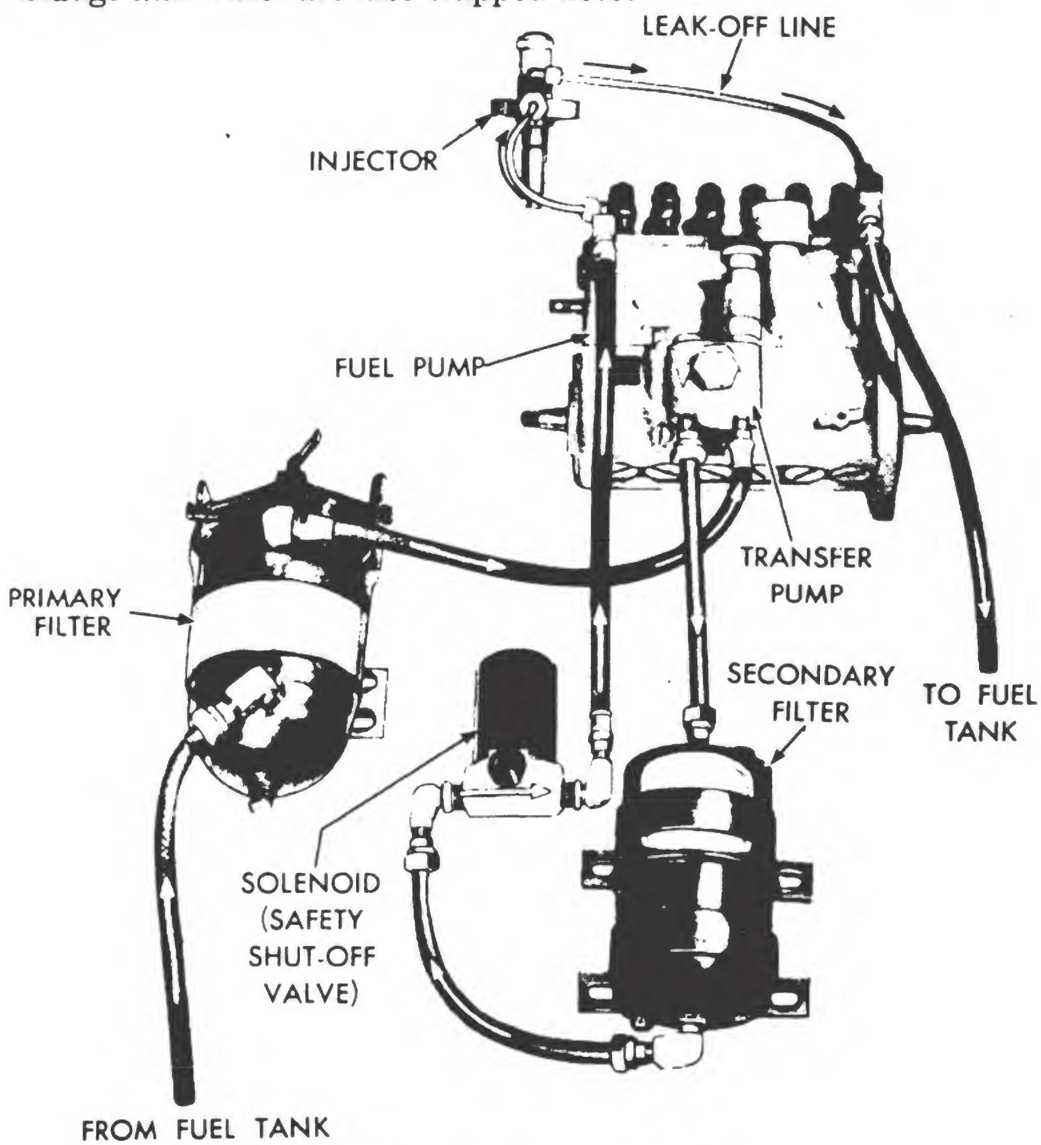


Figure 194.—Diesel-engine fuel system.

The clean fuel oil flows through a safety shut-off valve (not found on all Diesel engines) and over to the FUEL-INJECTOR PUMP. At this point the fuel gets a big boost in pressure which sends

it scooting over to the INJECTORS mounted in the cylinder heads. As each injector opens, fuel oil is sprayed into the cylinders and ignited by the high heat of compression.

Notice that leak-off line. There is one for each injector. The injector doesn't use all the fuel supplied to it. The leak-off line carries the extra fuel back to the fuel tank.

Pointers on the Fuel System

The fuel strainers will do their job longer if the fuel oil in the fuel tank is clean. That's another one of your jobs—keeping dirt and water out of the fuel tank.

Dirt can be kept out by keeping the fuel tank clean and straining the fuel before placing it in the tank. A funnel with a 200-mesh screen is your best insurance against dirt entering with the fuel.

Make sure that the fuel tank is refilled AFTER the engine is removed from the line. Leaving a half-filled tank overnight

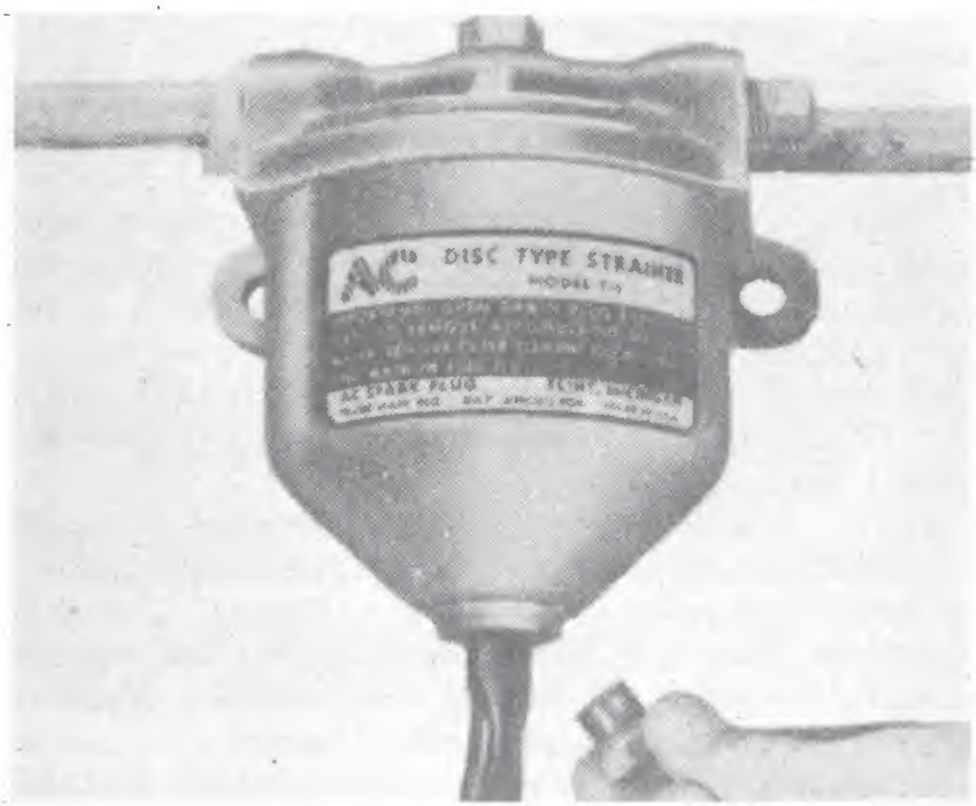


Figure 195.—Draining the fuel filter.

is inviting water to form by condensation on the uncovered sides and top.

The fuel strainer and filter on the Diesel engine will require replacing and cleaning. The manufacturer's manual for the particular engine you are working on will tell you how and when this should be done. Most of the filters will have a drain plug for removal of sludge and water. In general, the filters should be drained once a day. Figure 195 shows how simple the process is. This is done, of course, with the engine stopped. After the drain bowl is empty, be sure to replace the drain plug.

A Diesel engine will run best on the fuel oil that is recommended for it. The fuel-oil specifications will be found in the manufacturer's instruction book that accompanies each set. Whenever possible, use that fuel oil. But you may run into emergencies. Here's a tip: if you can't obtain Diesel fuel oil, and the engine must be put into operation, USE GASOLINE. It will work in a Diesel. A few quarts of lubricating oil mixed with the gasoline will help the operation of the engine. However, gasoline should not be used longer than is absolutely necessary.

GASOLINE-DRIVEN GENERATOR SETS

Gasoline engines come in handy as prime movers for generating sets. They are a lot lighter than Diesel engines. This feature makes them naturals for portable power units. In most cases gasoline-driven generators are used for emergency purposes or where the power drain is small. They're much easier to start than Diesels but have a tendency to change their speed under heavy loads.

The one-cylinder putt-putt in figure 196 is about the simplest you'll find in an advanced base. It will handle loads up to 1.5 kilowatts of a.c. power at 60 cycles and 115 volts. This makes it ideal for operating motors, tools, equipment, and supplying current for lighting. A starting rope wrapped around the flywheel kicks it off just like an outboard motor.

Some gasoline-driven generators are big enough to handle 15 to 30 kilowatts of a.c. power. These large machines are

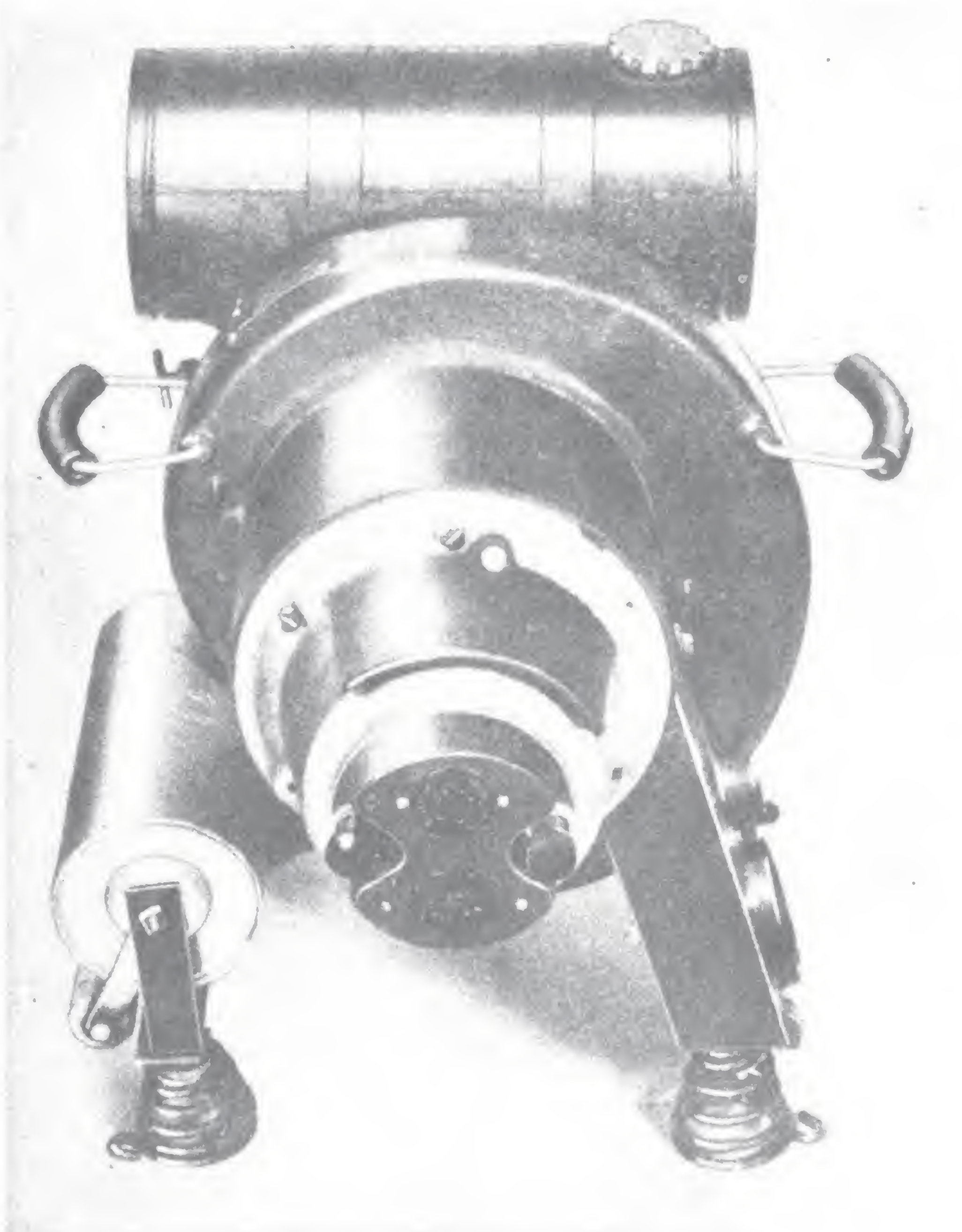


Figure 196.—Gasoline-driven generator set, 1.5 kw.

sometimes used as emergency stand-bys in the central power stations. The one shown in figure 197 is mounted on skids and has a weatherproof metal housing. This extra equipment makes it useful as a portable set for outdoor operation.

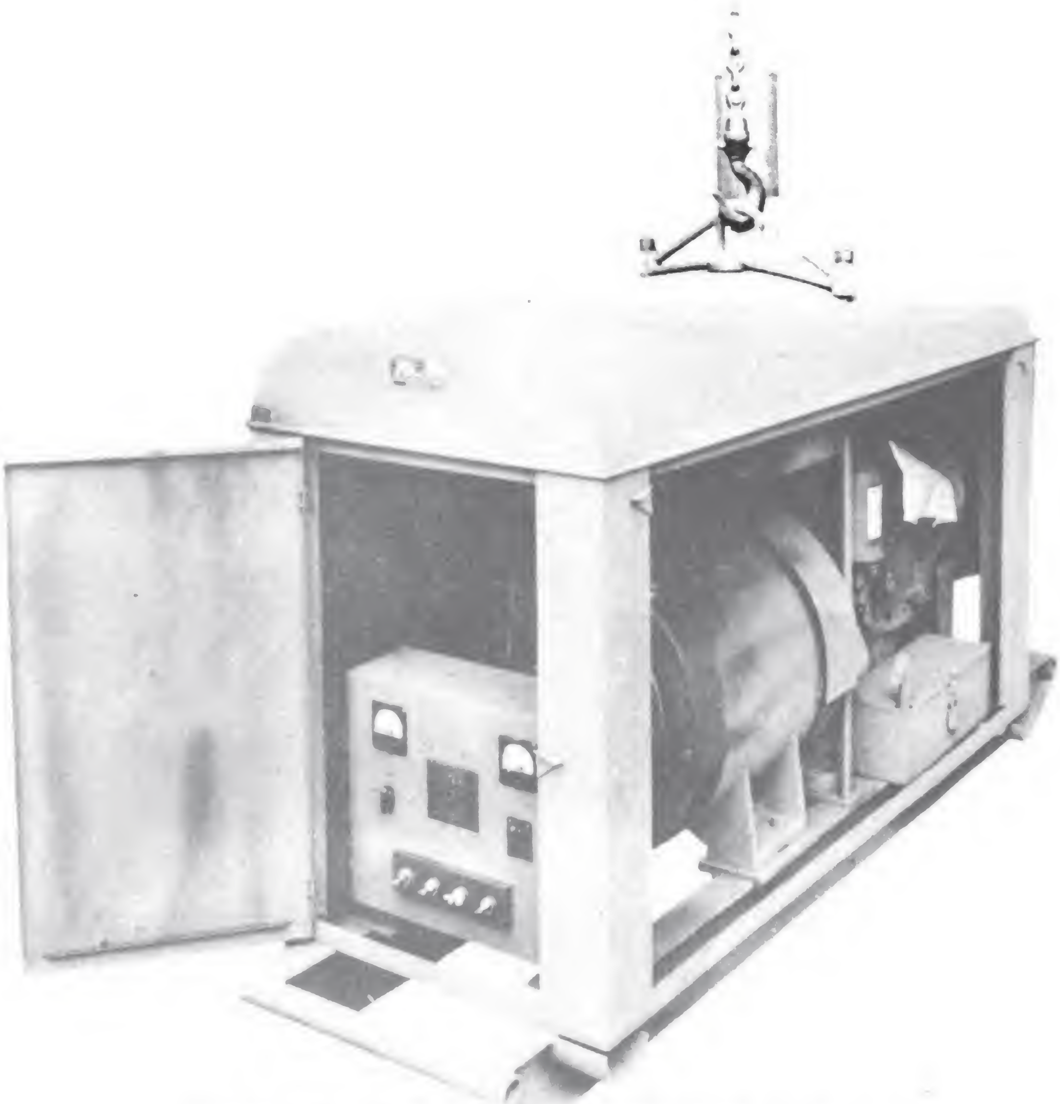


Figure 197.—Gasoline-driven generator set, 15 kw, a.c.

HOW THE GASOLINE ENGINE WORKS

Like the Diesel engine, the gasoline engine changes heat energy to mechanical energy. In fact, the physical construction of the gasoline engine is very much the same as the Diesel. There are pistons, cylinders, connecting rods, and a crankshaft and engine block in each. There is also a cooling system to cart the heat away; a lubrication system to reduce the friction of moving parts; an air system to supply oxygen for combustion in the cylinders; and a fuel system to supply fuel.

There are two differences between gasoline and Diesel engines: the method of introducing the fuel and air into the cylinder

and the means by which the compressed fuel and air are ignited in the cylinders.

In a Diesel engine the air is admitted to the cylinder on the intake strike of the piston. The fuel (fuel oil) is sprayed into the chamber AFTER the air has been compressed. In the gasoline engine the fuel (gasoline) and air are mixed together BEFORE being admitted to the cylinder. Figure 198 shows how it's done. The intake stroke of the piston sucks air through the air cleaner into the CARBURETOR.

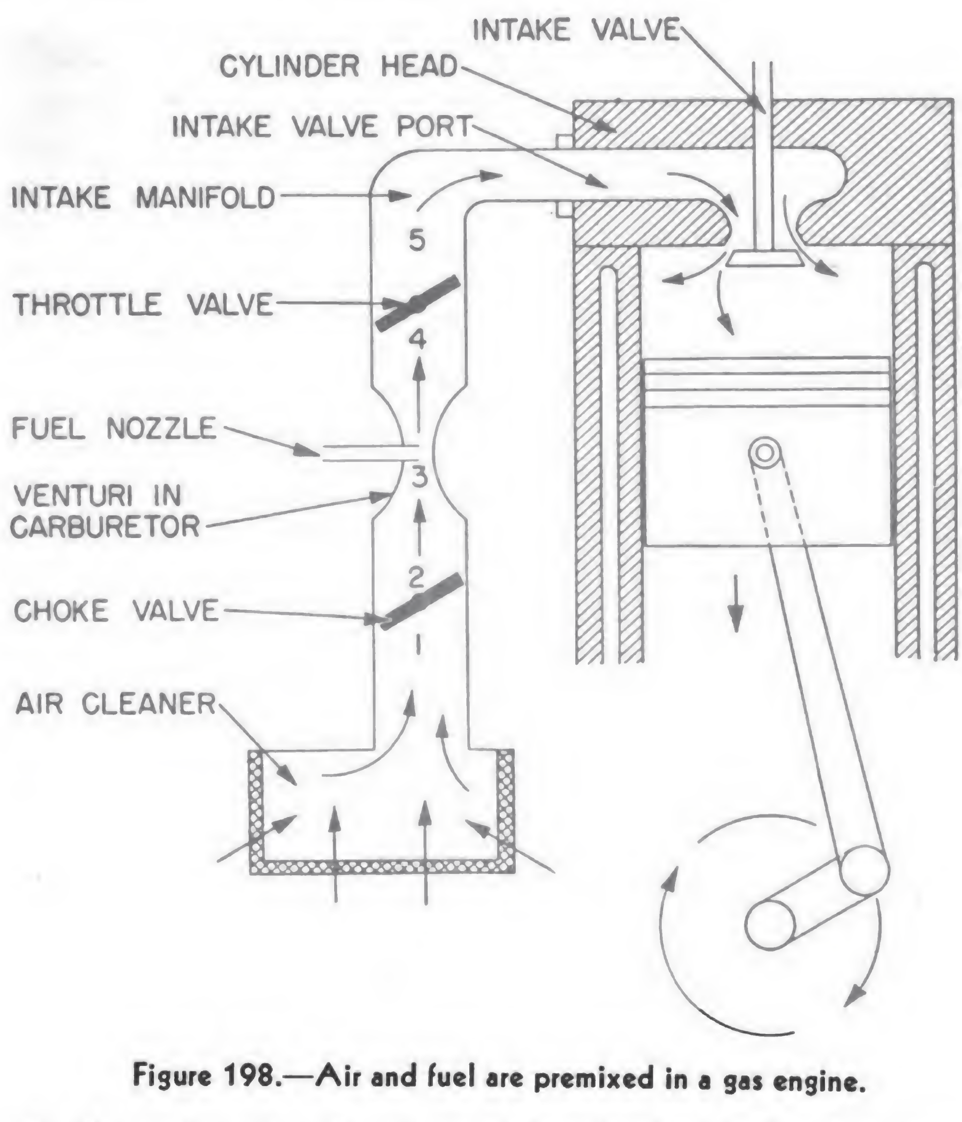


Figure 198.—Air and fuel are premixed in a gas engine.

In the carburetor, the clean air is mixed with gasoline (vaporized) from the fuel tank. The air and gasoline mixture continues on to the INTAKE MANIFOLD which is connected to the

cylinder head. An INTAKE VALVE admits the air-gasoline mixture into the cylinder.

The Diesel engine produced combustion by using the heat of compression. In the gasoline engine a SPARK is introduced into the cylinder. This spark ignites the air-gasoline mixture just as the piston completes its compression stroke. The ignited gases expand and the piston is pushed down into the power stroke. The exhaust stroke of the piston forces the burned gases out of the cylinder chamber.

GASOLINE-ENGINE IGNITION SYSTEM

Just where does that ignition spark come from? In the small gasoline engines that are started by hand, the source of the spark is a MAGNETO. The larger engines, which use a starting motor, have a BATTERY.

Battery Ignition System

Let's talk about the battery ignition system first. Basically, it consists of the BATTERY, IGNITION SWITCH, IGNITION COIL, DISTRIBUTOR, and SPARK PLUGS. Connect these parts together with wire and you have the circuit shown in figure 199.

Take a look at the spark plugs first. In figure 199 they are shown hanging in the air. Actually, each plug is screwed into a cylinder through an opening in the cylinder head. On the lower part of the plug are two electrodes separated by an air-gap. The middle electrode has an insulated path right through the center of the plug and is connected to the wire at the top. The side electrode is welded to the metal side of the plug. This electrode is grounded when the plug is screwed in the cylinder head.

Inside the cylinder, then, you have the spark plug electrodes separated by an air gap. If a high voltage is impressed across the electrodes, a spark will jump the gap. The high voltage can't come directly from the battery. The battery produces only a small d.c. voltage. The big question is what can be used to increase the battery voltage? The answer is the IGNITION COIL working with the DISTRIBUTOR.

Shift over to figure 200 for a better view of the ignition system. Notice that the ignition coil is nothing more than a

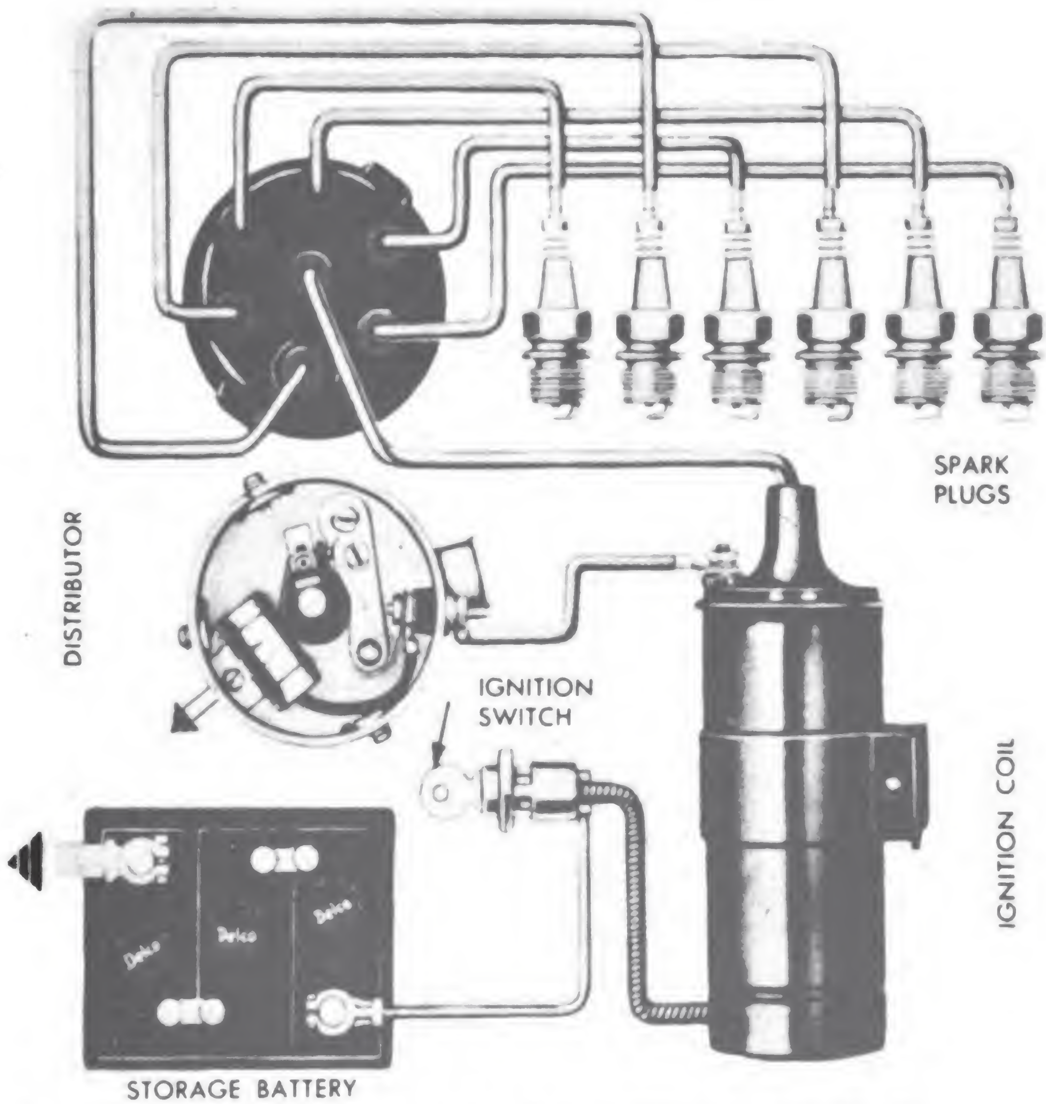


Figure 199.—Battery ignition system.

step-up transformer. The primary winding is connected between the battery and the contact arm of the distributor. The distributor contains a cam mounted on a rotating shaft. The shaft is connected to the crankshaft of the engine. As the cam rotates, it forces the contact arm to open and close two contact points.

When the ignition is turned on, the battery voltage is impressed across the primary winding of the ignition coil. Current flows through the primary when the contacts in the distributor are closed. A magnetic field is produced. The magnetic

field is steady because the current is steady. As a result, no voltage is induced in the secondary windings. Now suppose the cam comes around and kicks the contact points open. The current in the primary winding stops flowing. The magnetic field collapses back into the primary winding. In doing so, it

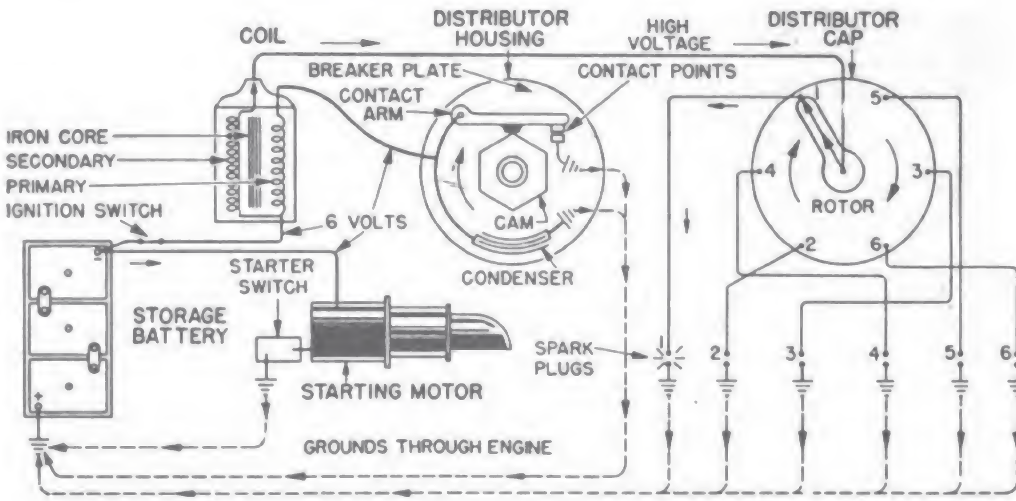


Figure 200.—Working parts of the ignition system.

cuts the many turns of the secondary winding, inducing a very high voltage in it. The contact points are opening and closing many times a second. This produces a steady stream of high voltage surges in the secondary of the ignition coil.

Now, you've got the high voltage for the spark plugs. But your work isn't done. You've got to shoot those high voltage surges over to each spark plug at the proper time. Use the distributor for this job also.

A rotating arm, or rotor, fits on the same shaft as the cam. The high voltage surges are brought over to the rotor. As it rotates, the rotor sweeps by a set of distributing pins. Each distributing pin is connected through cables, to the individual spark plugs. Thus, each high voltage surge is distributed to the proper spark plug in the proper firing order.

Magneto Ignition System

When an engine is manually cranked, a MAGNETO is used instead of a battery to fire the spark plugs. The magneto, itself, is a simple a.c. generator. In most cases the magneto,

ignition coil, and distributor are housed in one unit. Figure 201 shows a typical magneto unit mounted on the side of a gasoline engine.

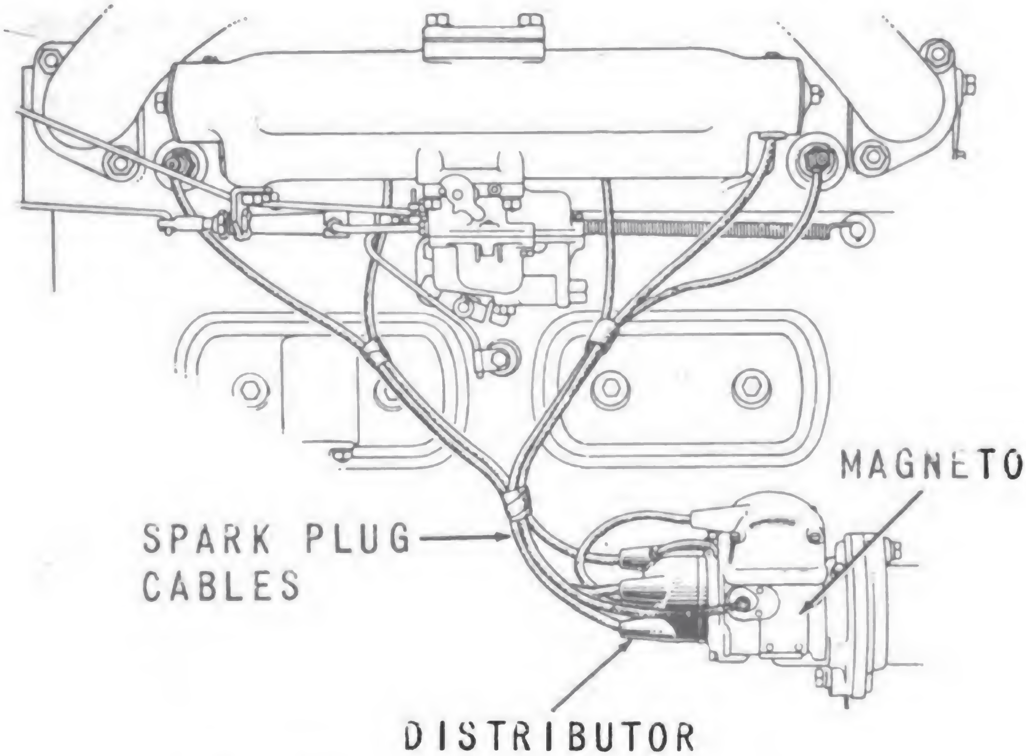


Figure 201.—Magneto unit mounted on engine.

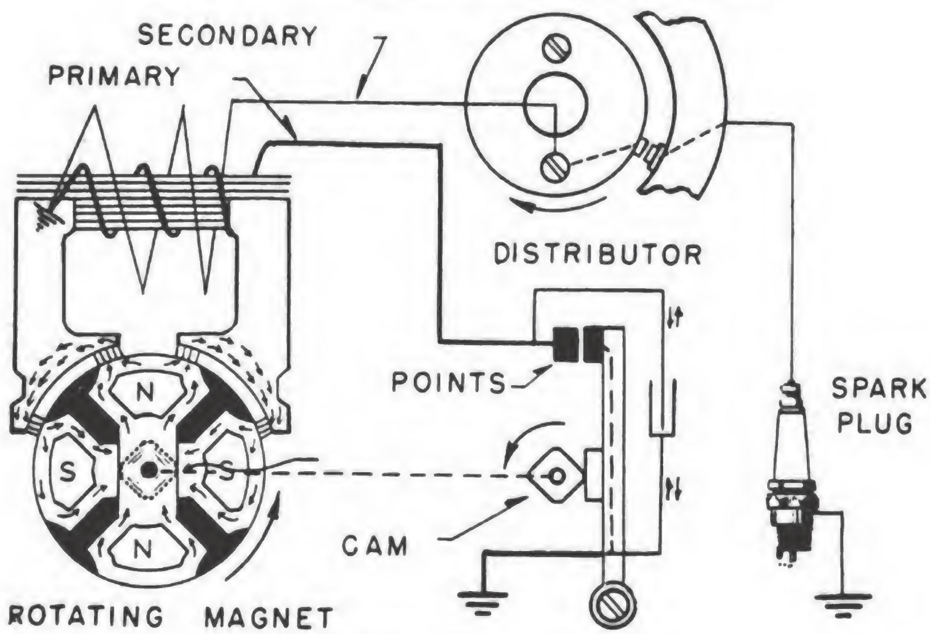


Figure 202.—Magneto circuit.

Just exactly how the magneto works is shown in figure 202. A rotating magnet (armature) produces a changing magnetic field in the iron core. The primary and secondary windings of the ignition coil are wound on this iron core. When the contact points of the distributor are closed, an alternating current is induced in the primary winding. The contacts open just as the current in the primary reaches a maximum value. The magnetic field produced by the primary current collapses. The high voltage induced in the secondary windings is then distributed to the spark plugs by the distributor.

Figure 203.—Spark-plug adjustment.

Pointers on the Ignition System

Both a battery and a magneto ignition system will take up some of your maintenance time. You will be required to service the spark plugs. A bad spark plug causes misfiring of the engine. When this happens, the output of your generator unit is affected.

A spark plug is easily removed for inspection. Check the porcelain insulation. If it is cracked, replace it with a new plug. Improper electrode air gap must also be remedied. A feeler gage is used to measure the distance between the electrodes (figure 203). The proper distance is given in the manufacturer's manual. You set it to this distance by bending the outer electrode. Never adjust the air gap by bending the center electrode.

The air-gap distance between the contact points on the distributor is also critical. This is another spot you can get to without tearing down half the engine. Removing the distributor cap exposes the assembly. The air gap should be measured when the movable contact arm is exactly on the point of one cam lobe. This is shown at point *A* in figure 204. The feeler gage is then inserted between the two contact points *B*, (figure 204). Notice that the stationary contact point is mounted on a screw and held in place by a lock nut. You can adjust the air gap by loosening the lock nut and turning the screw in the proper direction. Be sure you retighten the lock nut.

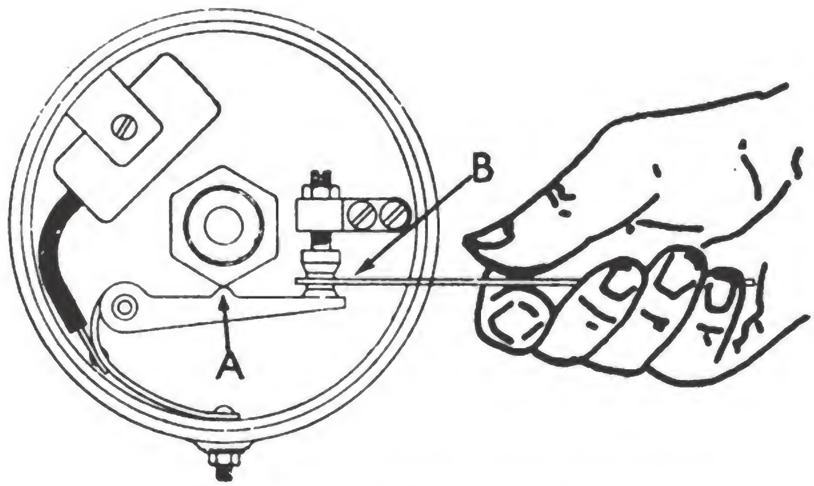


Figure 204.—Adjusting distributor air gap.

There's not much you have to be told about the battery. You've been given all the answers in chapter 3 of this manual. Your main job will be to keep the battery in tiptop shape. You do this by taking regular hydrometer readings of the cell, replacing water lost by evaporation, and keeping battery and battery connections clean.

THE STARTING MOTOR

To start a gasoline engine, you must apply a turning force to its crankshsaft. The small advanced base gas-driven generators call for muscle power. They're manually cranked. The larger engines get their initial push from a STARTING MOTOR.

Rugged is the word for the starting motor. It handles a large starting current (300 to 600 amperes) and turns a heavy load. The armature and field coils are in series, which gives the motor a high starting torque. Electrical energy is supplied by the battery.

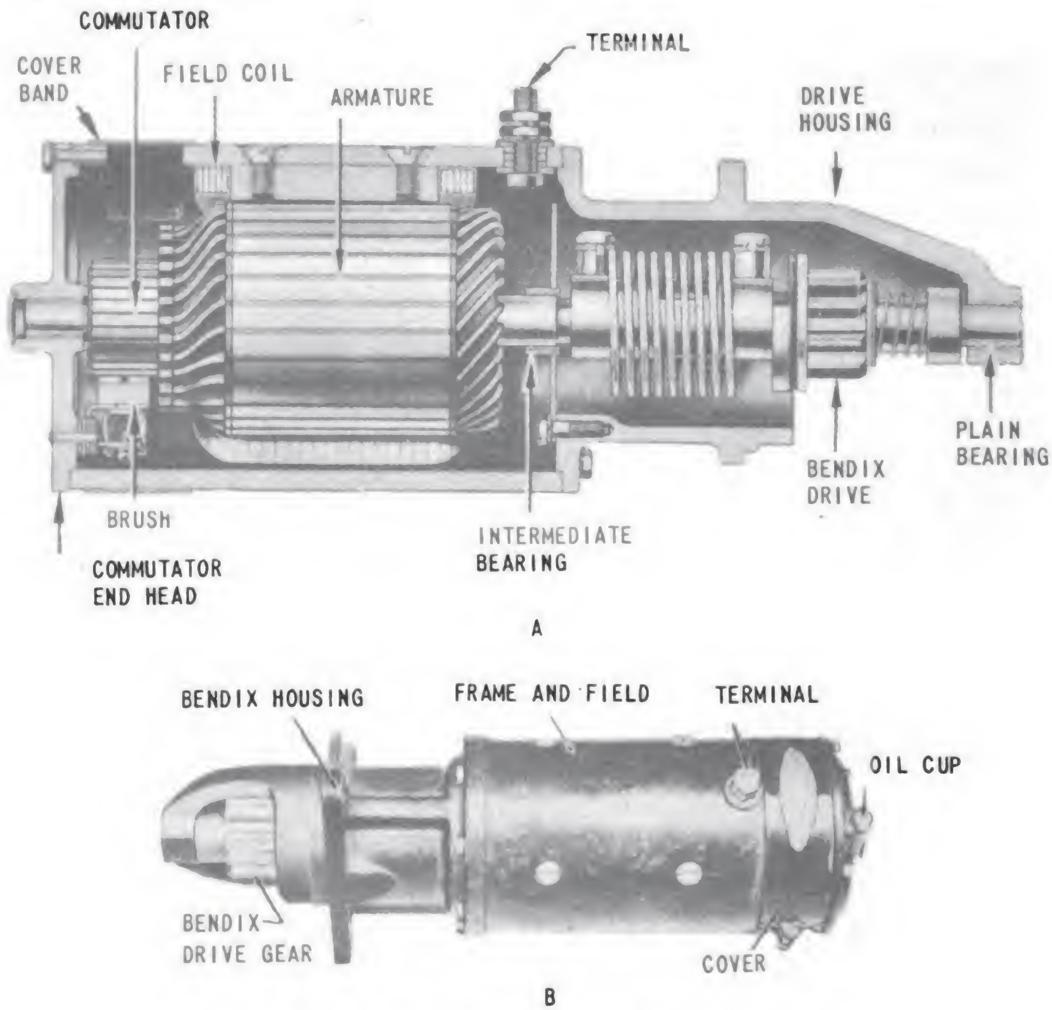


Figure 205.—Starting motor with Bendix drive.

Figure 205 shows a typical starting motor. Slice it in half and you get the cross-sectional view shown in the same figure. Everything to the left of the DRIVE HOUSING is old stuff to you. It contains the parts of the starting motor. In the drive housing are the gears which transmit the turning motion of the motor to the crankshaft. When the starting motor is mounted on the engine, these gears are in a position to mesh with those on the flywheel.

This particular drive is known as a BENDIX DRIVE. Here's how it works: pressing the starting button causes a solenoid to close the circuit between the battery and the starting motor. Current from the battery travels through the field coils and armature of the motor. The armature starts to rotate. The Bendix drive is automatically thrown forward and meshes with the flywheel gear. The engine is forced to turn and start. The engine, after starting, rotates faster than the starting motor. This action automatically disengages the Bendix drive.

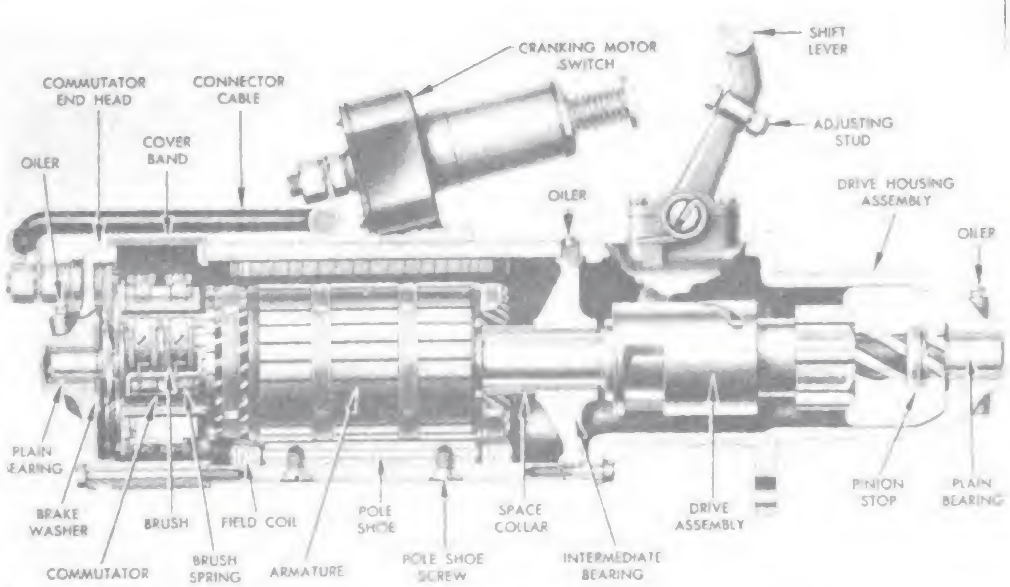


Figure 206.—Sectional view of starting motor with Dyer drive.

Some of the heavier engines use a DYER DRIVE with their starting motor. The Dyer drive differs from the Bendix in that the driver gear is meshed with the flywheel BEFORE the motor starts. Figure 206 will help you to understand this action. A manual control, or SHIFT LEVER, is pulled to the left. This action pushes the drive gear into mesh with the flywheel. At the same.time, the shift lever contacts the starting-motor switch. This switch connects the battery to the starting motor. On some engines the shift lever is automatically pulled back by a solenoid.

Pointers on the Starting Motor

Cranking a cold engine is like trying to whip a bowl of molasses. And it's the starting motor that takes all the strain. It's built for heavy duty, sure, but for only 30 seconds of it at a time. If the engine won't kick over in 30 seconds, release the starter button. Allow about 5 minutes for the starting motor to cool down—then try it again.

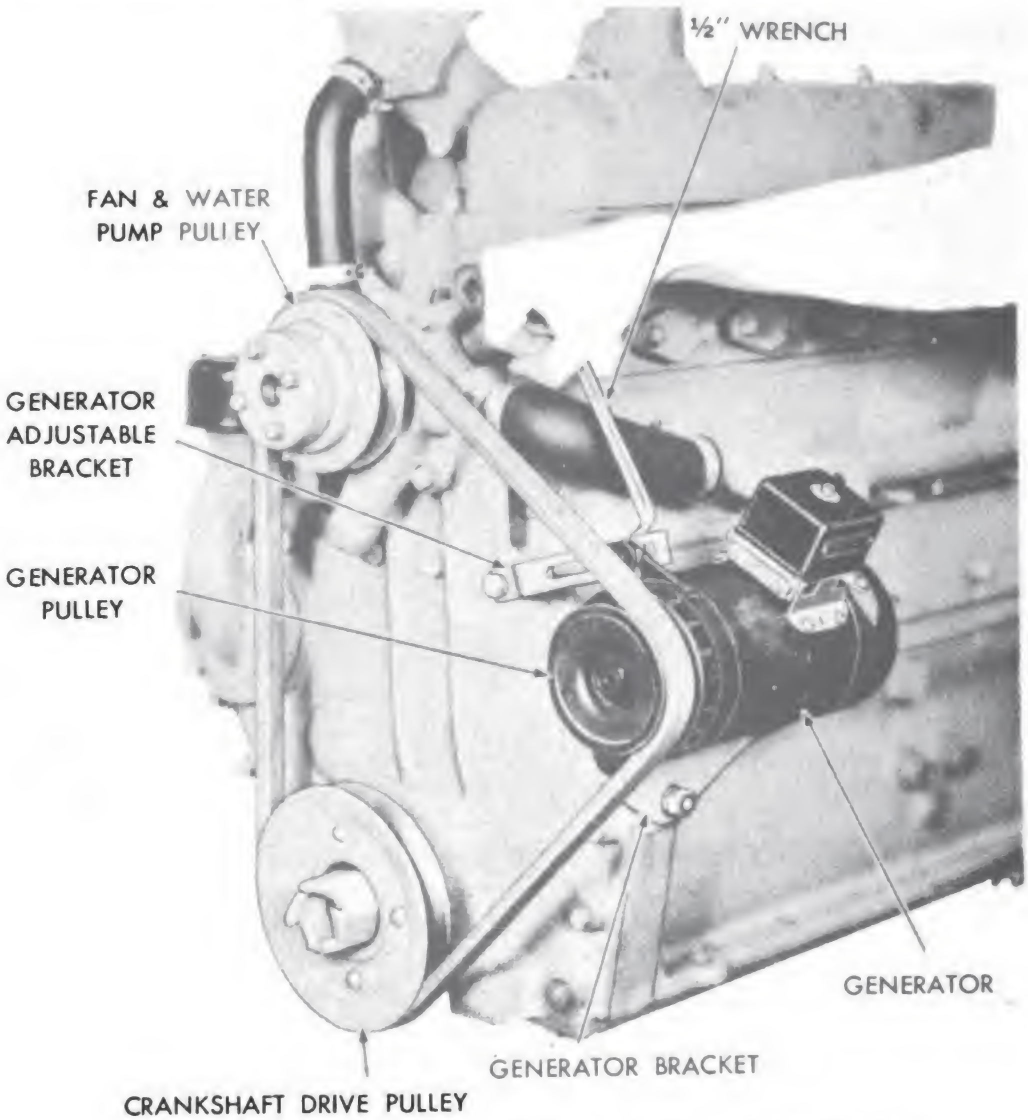


Figure 207.—Charging generator mounted in position.

Maintenance of the starter motor is right up your alley. You already have the know-how on cleaning the commutator and replacing worn brushes. And it's a good idea to inspect the

starting circuit wiring regularly. That goes for the wiring around the brush rigging from battery to ground, from battery to the starting switch, and from the switch to the motor. Check for loose or corroded connections and damaged insulation.

Follow the manufacturer's manual for the type of motor lubricant to use, how often to use it, and the points of application on the starting motor.

THE CHARGING GENERATOR

Each time you start your engine you drain the battery of some of its stored energy. If you expect the battery to start the engine again you must restore this energy. It won't be necessary to remove the battery to a charging rack. The CHARGING GENERATOR on the engine will do the job.

The charging generator is a small shunt-wound d.c. generator. The generator is mounted on an adjustable bracket at the front end of the engine. It is driven by a pulley arrangement and a fan belt as shown in figure 207.

Remember that the charging generator is a source of electricity, while the battery is a storage place. With the engine running at normal speed, the charging generator supplies the energy for the ignition system. The battery takes over when the engine is idling.

Since the output of the charging generator depends on engine speed, some form of voltage control is necessary. In figure 207 you probably noticed a little black box on top of the charging generator. Remove the cover and you'll find a couple of electromagnets, each with a set of contacts (figure 208).

One electromagnet called a REVERSE-CURRENT CUT-OUT RELAY, acts as circuit breaker. If the voltage of the charging generator falls below that of the battery, the contacts open, breaking the circuit between the battery and the charging generator. This prevents the battery from discharging back through the generator.

The other electromagnet is termed a VOLTAGE REGULATOR. Its job is to keep the voltage output of the charging generator at a fairly steady value, and thus prevent overcharging of the

battery. When the generator voltage is equal to or below that of the fully-charged battery, the contact points of the relay remain closed. But when the generator voltage tries to go above that of the battery, the contacts open. This action automatically inserts a resistance in series with the field coils

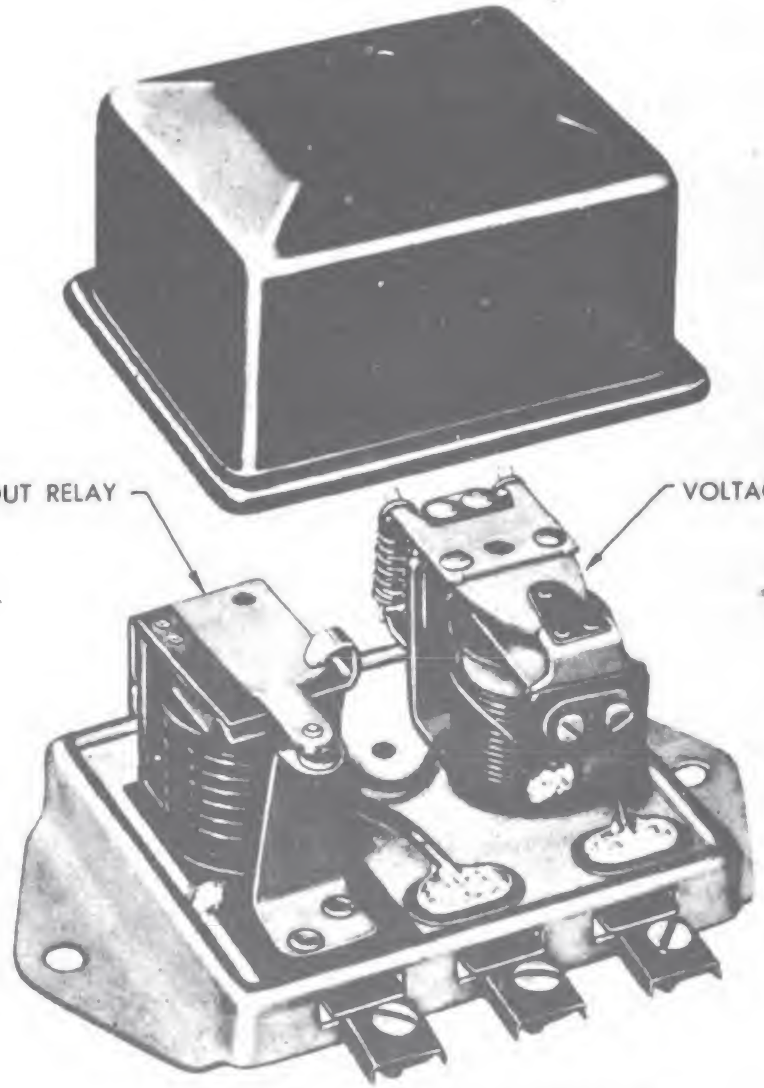


Figure 208.—Voltage-regulator unit.

of the generator. The field strength is reduced, the armature coils cut fewer lines of flux, and the generator voltage decreases.

Pointers on the Charging Generators

Keeping the charging generator in good condition is a very important part of your job. You know all about the mainte-

nance and care of d.c. generators, so that's the least of your worries. It's pretty important that your fan-belt tension be adjusted as recommended in the manufacturer's manual. You can adjust the tension by shifting the charging generator on its bracket. This is shown in figure 207.

The contact points on the regulator relays will need periodic cleaning. This is done easily by rubbing a piece of crocus cloth between the contact points. You can see this operation being performed in figure 209. Don't attempt to make any adjustment in the settings of the relays.

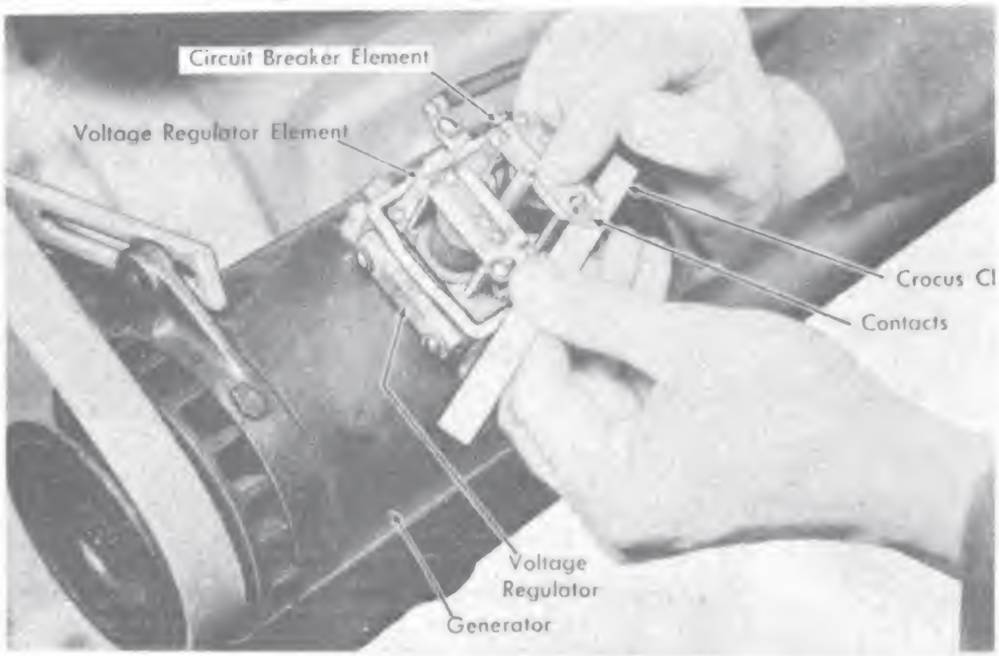


Figure 209.—Cleaning the regulator contacts.

THE CONTROL PANEL

Every advance-base generating set will have a control panel. Some will have just a few meters and controls, others will look like the panel board of a Buck Rogers rocket ship. It all depends on their size and the type of electrical equipment they supply with power.

The small one-cylinder gas-driven generator in figure 210 is a good example of a simple control panel. All that you'll find on it will be a voltmeter and a rheostat. The rheostat CONTROLS the amount of voltage generated by the alternator;

the voltmeter INDICATES the amount being generated. The throttle, which controls the engine speed, is mounted on the other side of the engine.

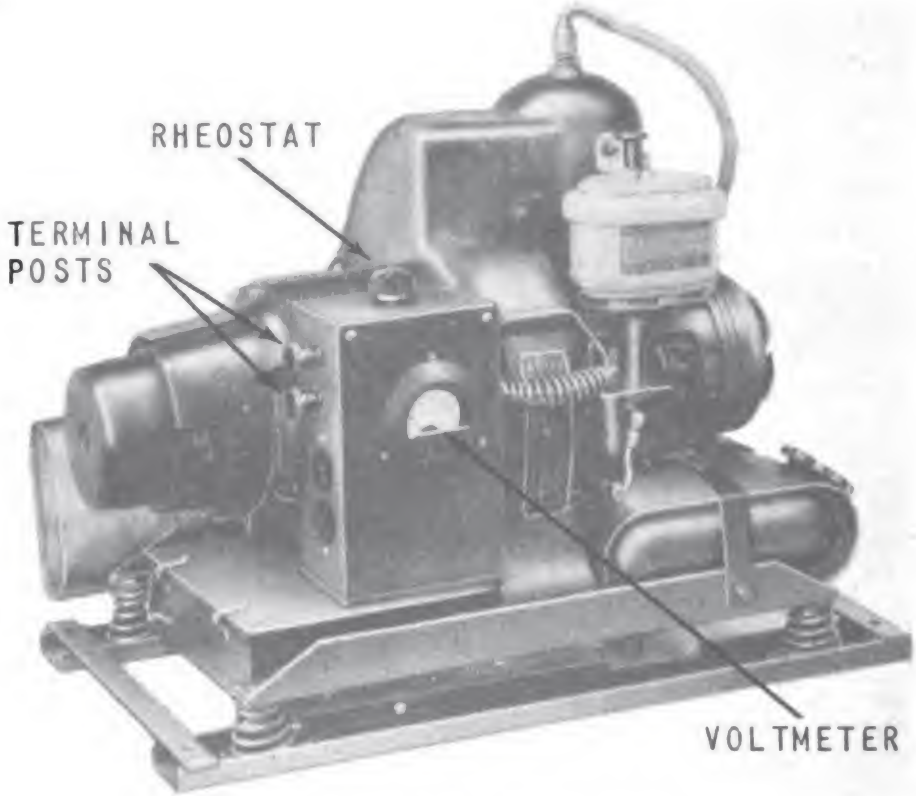


Figure 210.—Simple control panel.

Now take a look at figure 211. This is what you're going to see when you look at the control panel of a big job. It's part of the General Electric, Model 6016-C, Diesel-driven generator set. Every meter and control is marked. Operating the unit becomes easy if you know the part each meter and control plays.

The STARTER SWITCH controls the starting motor. Pushing the starter switch completes the circuit between the battery and the starting motor.

The THROTTLE normally controls the amount of fuel fed into the cylinders of the engine and therefore controls the speed of the engine. Most of the advanced base generating units are equipped with a GOVERNOR. The governor is an

automatic throttle that maintains a constant engine speed by counteracting changes in load. Thus, the frequency output of the generator is kept constant.

The AIR-HEATER SWITCH controls the current to an ignition system in the air-heater unit installed in the engine. The air-heater unit preheats the ingoing charge of air to the cylinders. This unit is used only for cold-weather starting. The air-heater switch is turned off after the engine has started. It is common practice to preheat the large Diesel engines for cold-weather starting.

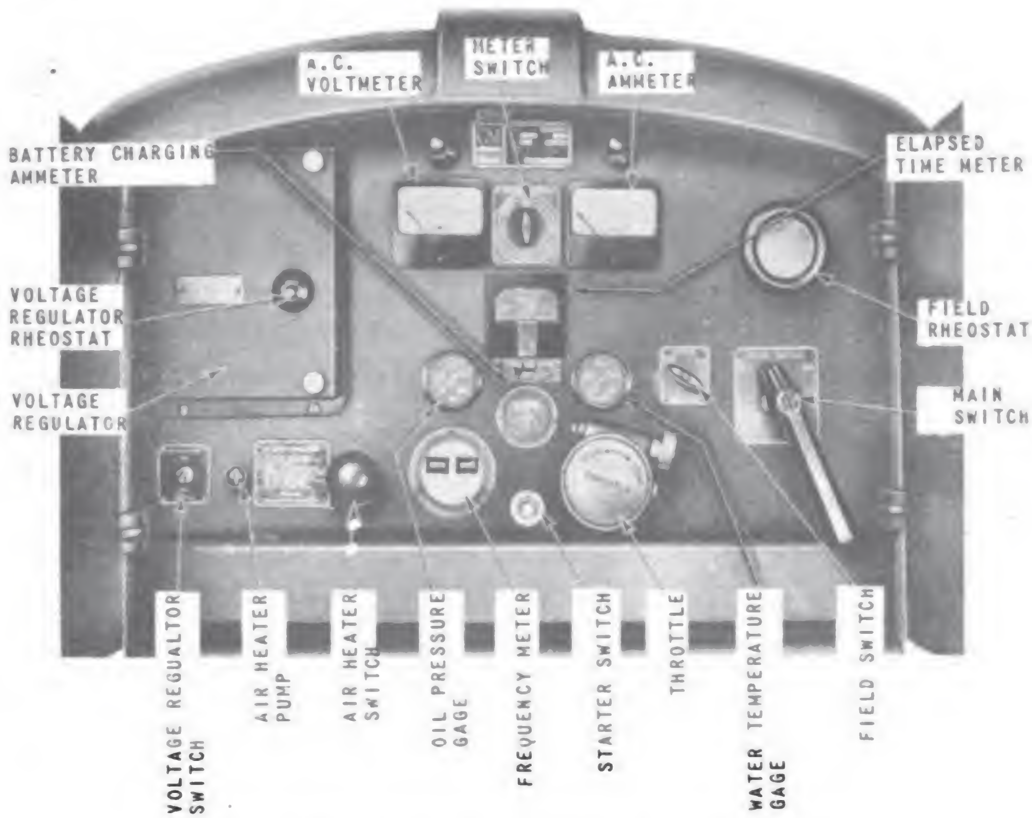


Figure 211.—GE, model 6016-C, control panel.

The AIR-HEATER PUMP is used in conjunction with the air-heater switch. Operating this pump causes oil to flow under pressure from the air-heater unit spray nozzle. The ignition system in the air-heater unit ignites the oil spray. The heat from this miniature oil burner warms the ingoing charge of air.

The ELAPSED-TIME METER indicates the number of hours the engine is in operation. You will record the reading of the

elapsed-time meter in the log. It is used to determine when the engine is ready for maintenance or lubrication.

The OIL-PRESSURE GAGE indicates the engine oil pressure. A quick look at this gage tells you the condition of your lubricating system. The normal operating pressure averages about 30 pounds per square inch.

The WATER-TEMPERATURE GAGE indicates the temperature of the cooling water in the engine. The water temperature of a gasoline engine should read 160-170° F. under normal operations. You know your Diesel is perking along o.k. when the temperature gage reads 180-185° F.

The BATTERY-CHARGING AMMETER records the amount of current sent over to the battery from the charging generator. It also indicates the amount of current being delivered by the battery on discharge.

The FIELD SWITCH controls the output of the exciter. In the OFF position, the switch disconnects the exciter field from the exciter armature. In the ON position, the exciter field is connected to the exciter armature. Since the exciter supplies current to the alternator-field coils, the field switch also controls the alternator output. Before the engine is stopped, the field switch is thrown to the OFF position. This action disconnects the exciter field and at the same time shunts a FIELD-DISCHARGE RESISTOR across the exciter-field coils. The field-discharge resistor absorbs any high voltages which might result from the quick opening of the field circuit.

The FIELD RHEOSTAT is a manually controlled variable resistor that is placed in series with the exciter field. It controls the voltage output of the exciter. The value of the exciter voltage determines the amount of exciter current flowing in the alternator field coils. The amount of exciter current, in turn, controls the voltage output of the alternator. Thus, when you adjust the field rheostat, the result is seen as an increase or decrease of the voltage output of your generator unit.

The VOLTAGE REGULATOR is going to be one of your best pals. It makes your generator watch an easy job. Without the voltage regulator it would be necessary for you to change the field-rheostat setting each time the output voltage of your

generator unit varied from its normal value. The voltage regulator does this for you automatically. Like the field rheostat, the voltage regulator is a variable resistance in series with the exciter field. The resistance is varied automatically by a control unit. The control unit takes changes in generator voltage and converts them to changes in mechanical motion. The changes in mechanical motion will increase or decrease the voltage regulator resistance. In this manner the output of your generator is kept at a constant value.

The VOLTAGE-REGULATOR SWITCH in the ON position puts the voltage-regulator unit to work. With the switch in the OFF position you must use the field rheostat to adjust the voltage output of the generator unit.

The VOLTAGE-REGULATOR RHEOSTAT is a small variable resistor mounted on the voltage-regulator unit. It is in operation only when the voltage regulator is in the circuit. The setting of the voltage-regulator rheostat determines the value of voltage kept constant by the voltage regulator.

The A. C. VOLTMETER indicates the voltage output of your generator unit. When you adjust your field rheostat or voltage-regulator rheostat you will be watching the a.c. voltmeter. It will tell you when you have reached the generator's rated voltage output.

The A. C. AMMETER indicates the current output of your generator unit. Any overload or unbalancing of a line can be spotted with this instrument.

The METER SWITCH is necessary because this particular unit is a three-phase generator. Each position of the switch puts the a.c. voltmeter and a.c. ammeter in a different leg of the three-phase line. Thus you are able to reach the voltage across any two legs and the current in any one leg. The OFF position of the switch disconnects the ammeter and voltmeter completely.

The FREQUENCY METER measures the frequency (cycles per second) of the voltage generated by the alternator.

The SYNCHRONIZING LAMPS are used when the generator unit is being paralleled with another generator.

The SYNCHRONIZING-LAMP SWITCH controls the synchronizing circuit.

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The MAIN SWITCH opens or closes the circuit between the generator and the load. Remember that it doesn't shut the engine off. In most cases the main switch will have a built-in CIRCUIT-BREAKER. This device will automatically open the main switch whenever a continuous overload current appears on the line.

STARTING THE ADVANCED-BASE DIESEL ENGINE

Once a Diesel gets going, it's smooth sailing all the way. But getting it to start from a dead stop is a real problem. First of all, a full Diesel uses the heat of compression to ignite the fuel in its cylinders. In starting, most of that heat is lost in warming the cold cylinder walls and pistons. Secondly, to get that high heat of compression it is necessary for the pistons to cram the air into a very small space. That also takes a lot of outside work.

The fact that advanced base Diesels do get started means that the problem has been licked. In fact it has been licked by three different methods.

Method No. 1 uses an in-built gasoline starting system. Method No. 2 uses an AUXILIARY GASOLINE ENGINE. Method No. 3 uses an ELECTRIC STARTING MOTOR.

Any advanced base Diesel generating unit is going to use one of the three methods. Starting the Diesel is part of your job, so you should know the general procedure for each method. One way for you to learn is to show you how three manufacturers use the three different starting methods. That doesn't mean, of course, that you'll be able to step up and operate the first Diesel unit that you run across. It's still going to take a lot of LISTENING on your part before you can begin flipping switches and turning knobs.

Combination Gasoline-Engine Starting

All INTERNATIONAL HARVESTER Diesel engines have an in-built gasoline starting system. It should be borne in mind that the gasoline cycle is to be used for starting the engine and preheating the combustion chamber in preparation for

full Diesel operation. The engine, while operating on gasoline, cannot be used under load. The one shown in figure 212 drives a 15 kw alternator. You can operate this unit directly from the control panel (switchboard).

All that you have to do to change a Diesel engine to a gasoline engine is:

1. Add a spark plug to each cylinder.
2. Provide an ignition system.
3. Provide a means of decreasing the amount of compression in the cylinders.
4. Provide a gasoline-engine fuel system.

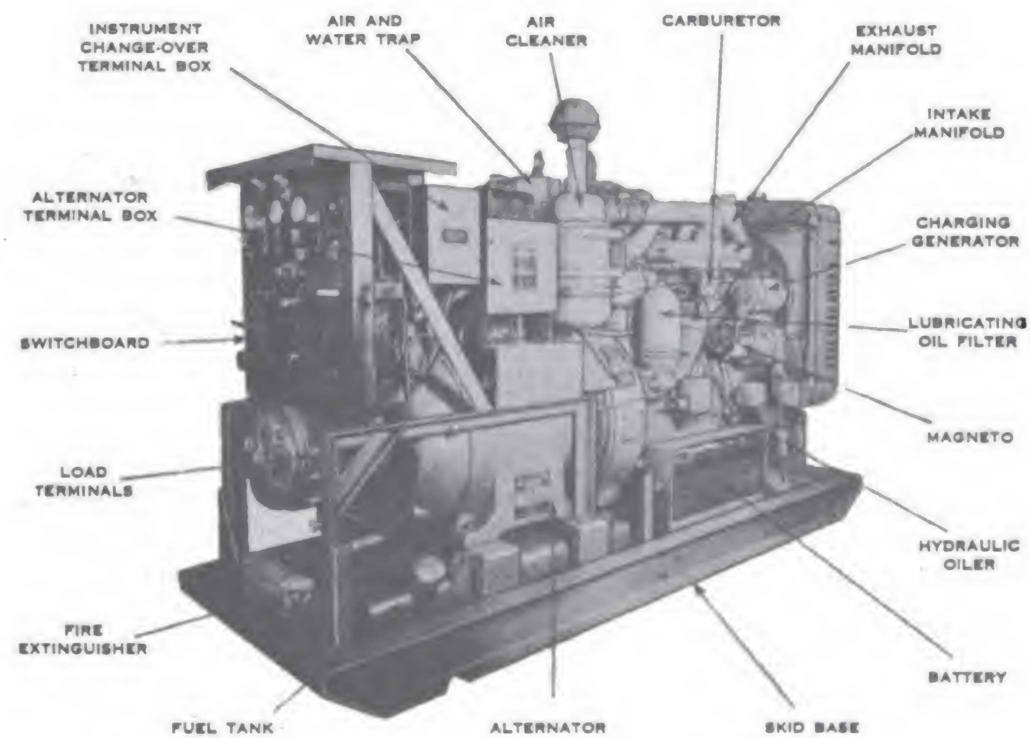


Figure 212.—Combination gasoline and Diesel driven generator.

All this is controlled by the COMPRESSION RELEASE.

Here are the steps in starting the Diesel engine:

Step 1.—Be sure that the MAIN SWITCH and the FIELD SWITCH are in the OFF position.

Step 2.—Pull the COMPRESSION-RELEASE control forward until latched for gasoline starting.

Step 3.—Press the STARTER BUTTON. When the engine starts, set the choke so that the engine runs without missing. Check the oil gage for proper pressure.

Step 4.—Change to Diesel operation by pushing the COMPRESSION-RELEASE control in until tripped. Immediately pull the GOVERNOR-CONTROL lever forward until latched.

With the Diesel started you're all set to get some power from the alternator. This is how you do it:

Step 5.—Throw the REGULATOR SWITCH to the OFF position. Turn the EXCITER-FIELD RHEOSTAT knob as far CLOCKWISE as it will go.

Step 6.—Keep an eye on the A.C. VOLTMETER and throw the FIELD SWITCH to the ON position.

Step 7.—Adjust the EXCITER-FIELD RHEOSTAT until the A.C. VOLTMETER reads about two volts MORE than the rated voltage output of the generator unit.

Step 8.—Check the FREQUENCY METER. It should read 61 to 62 cycles per second. Adjust the GOVERNOR CONTROL (throttle) to obtain this value.

Step 9.—You are now ready to apply the load. Throw the MAIN SWITCH to the ON position.

If you want to operate on automatic voltage regulation, substitute the following for *step 7*:

Throw the VOLTAGE-REGULATOR SWITCH to the ON position. Adjust the VOLTAGE-REGULATOR RHEOSTAT until the A.C. VOLTMETER reads the rated output voltage of the generator unit.

All you have to do to stop the engine is push the STOP BUTTON. Before you do this be sure to open the MAIN SWITCH and then the FIELD SWITCH.

Auxiliary Gasoline-Engine Starting

The CATERPILLAR Diesel engine uses the auxiliary gasoline engine method of starting. A small two-cylinder, four-cycle gasoline engine is mounted on the side of the Diesel engine. You can get a good view of this unit and its controls in figure 213. Notice that the exciter is not connected directly to the alternator shaft. It is mounted on top of the alternator and is belt-driven.

To start the Diesel engine do the following:

Step 1.—Place the COMPRESSION-RELEASE lever in the START position. This action reduces the high compression of the Diesel engine.

Step 2.—Move the THROTTLE into its latched position. This closes the Diesel fuel pumps.

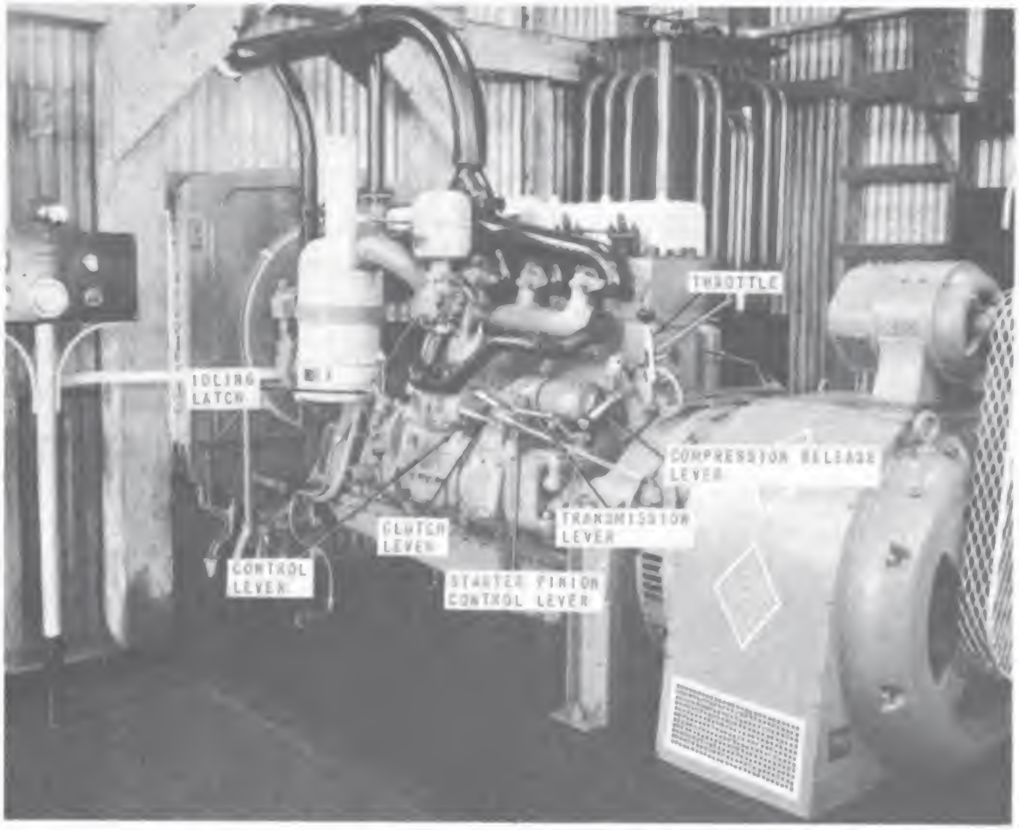


Figure 213.—Auxiliary gasoline engine and Diesel engine.

Step 3.—Disengage the starting engine from the Diesel engine by pushing the CLUTCH LEVER back as far as it will go.

Step 4.—Permit gasoline to flow from the starting engine's fuel tank by opening the fuel-tank valve. At the same time move the IDLING LATCH to hold the gasoline engine governor at an idling position.

Step 5.—Crank the gasoline engine with the electric starting motor. You start this action off by moving the CONTROL LEVER back.

Step 6.—Pull out on the STARTER-PINION CONTROL LEVER.

This puts the starting engine in a position to crank the Diesel engine. Keep the TRANSMISSION LEVER in HIGH.

Step 7.—Release the IDLING LATCH so that the gasoline engine will run at its high-governed speed. Then pull back on the CLUTCH LEVER until the gasoline engine begins to crank the Diesel engine.

Step 8.—Move the COMPRESSION RELEASE to the START position. The gasoline engine is now turning the Diesel engine over under high compression. This will warm the Diesel cylinder chamber up to a temperature necessary for starting.

Step 9.—Pull the THROTTLE back about half way. Fuel is now injected into the Diesel cylinders. As soon as the Diesel begins to fire push the CLUTCH LEVER in.

Step 10.—Stop the gasoline engine by closing the fuel-tank valve.

Step 11.—Allow the Diesel to idle about 5 minutes at half-throttle, then pull throttle back to full position. It's a good idea to let the engine run for 5 minutes at full speed before applying the load.

It won't be necessary to outline the steps in applying the alternator load. In general, they will be the same as steps 5, 6, 7, and 8 of the International Diesel operation.

Stopping this engine is a lot easier than starting it. After you pull the main switch and the field switch just push the throttle to the STOP position. This shuts off the flow of fuel to the Diesel cylinders. While the engine is slowing down, shift the COMPRESSION-RELEASE LEVER to the START position. And leave the Diesel fuel-tank valve open. Air has a hard time getting into a fuel system that is always full of fuel.

Electric-Motor Starting

You won't find a gasoline engine on a Diesel using an electric motor for starting. All that's necessary is a good heavy-duty electric motor linked right up to the Diesel engine. The General Motors model shown in figure 214 uses this method.

You couldn't ask for anything simpler than the following steps in starting:

Step 1.—Turn THROTTLE to a halfway position.

Step 2.—Press STARTER SWITCH to start the engine. As soon as the Diesel fires check the oil pressure.

Step 3.—Allow engine to run at half speed for about 5 minutes. Then turn throttle to full or RUN position.

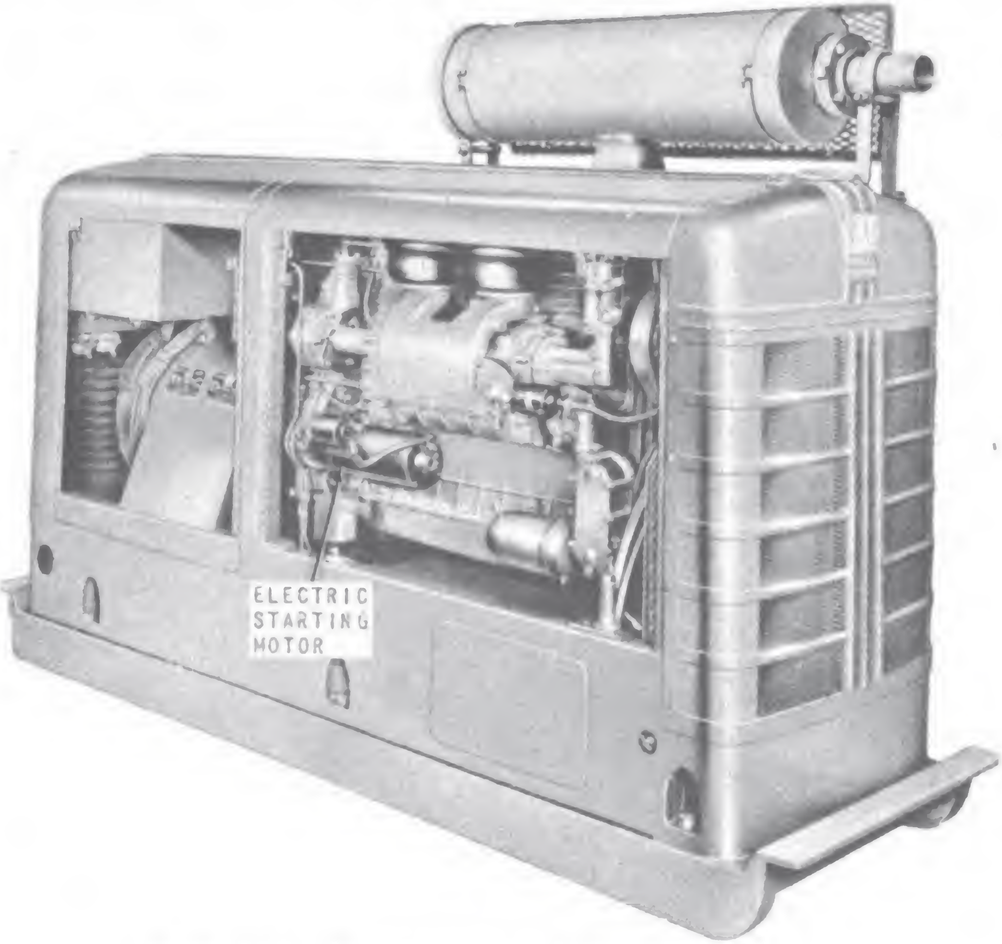


Figure 214.—Electric motor and Diesel engine.

To get the alternator operating just follow the general steps given for the International Diesel unit.

To shut down the Diesel engine, place the main switch and field switch in their OFF position. Then turn the THROTTLE back to STOP.

THE COMPLETE PICTURE

You're a new man in the outfit so the chief has you over at the generating station. He wants to give you the complete picture on the station layout.

The first thing you'll notice is that everything is in shipshape order. Most of the wiring is in conduit. No extra tools clutter up the floor. If you get hurt here it's no accident but simply your own fault.

Next on your tour of inspection are the generating units. There'll be a couple of MAIN GENERATORS similar to the one in figure 213. Each main generator is Diesel-driven and can produce 60 kw of power under load. Then there's an AUXILIARY GENERATOR. It is gas-driven and has a rated output of 10 kw.

The CONTROL PANEL (switchboard) will probably catch your eye next. It is usually mounted on the wall. You really don't need the chief to explain its set-up. You can see that it contains the meters and switches to control each generator.

The picture is completed after you examine the MAIN BUS BARS. After passing through the control panel, the output of each generator is tapped to this central distributing point.

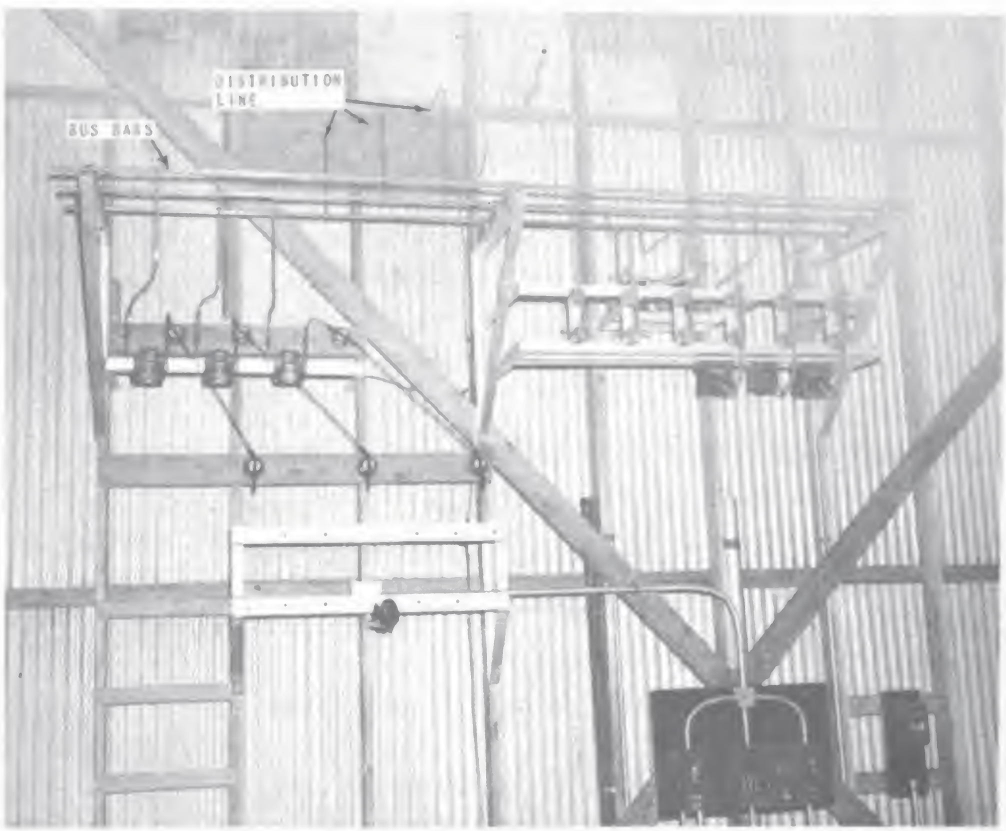


Figure 215.—Bus-bar installation.

It is nothing more than heavy copper bars which are capable of carrying high currents. Figure 215 shows you a typical bus bar for a three-phase installation.

The power lines which distribute the power to different sections of the area are tapped into the bus bar. One such distribution line can be seen at the top of the bus bar in figure 215.

OPERATING PROCEDURES

How much power you will have to send out from the station will depend on the hour of the day. Your lightest loads will be in the daytime and the early hours of the morning. One main generator can handle the load. The other can be shut down for any maintenance or repair work.

Heavy loads come at night. That means both main generators will be working at the same time. You now have 120 kw of power available.

Just hope that both main generators don't break down at the same time. It may not happen, but you want to be all set for just such an emergency. The emergency or stand-by unit will help you along. It's a matter of starting it up and connecting it into the bus bar. You want to remember that it only puts out 10 kw of power. It won't be able to handle the whole area load. That means you'll have to disconnect the lines leading to areas which can get along without power until the main generators are fixed.

STANDING THE GENERATOR WATCH

The chief hasn't been giving you this information for nothing. He knows that you will be standing a generator watch. And that puts a lot of responsibility on your shoulders.

You should be familiar with the METER LOG. A typical one is shown in figure 216. You will record the voltage and amperage reading of each generating unit on the meter log. And be sure to note the time you start up or shut down a unit. Any maintenance notes should also be entered in the log.

If your generator watch calls for starting up and operating a unit, the following hints will come in handy.

Date	Time	UNIT NO. 1785			UNIT NO. 942			UNIT NO. 3465			REMARKS
		Elapsed Time Meter	Volts	Amperes	Elapsed Time Meter	Volts	Amperes	Elapsed Time Meter	Volts	Amperes	
4/17/44	16.00	195.0	240	55	302.0	220	52	934.0	220	27	started up
"	17.30	196.5									added 2qts oil To #1785
"	21.00	200.0	221	54	307.0	221	49				shut down #3465

Figure 216.—Meter log.

Before starting:

1. See that the fuel tank is filled with Diesel fuel oil.
2. Fill the gasoline tank with gasoline (on Diesel engines started by gas).
3. Fill the radiator with water.
4. Check crankcase oil. Add oil if required.
5. Set the main switch and field switch to their OFF positions.

During operation:

1. Keep a check on the oil pressure gage.
2. Keep a check on the voltage across each leg of the line.
3. Watch the frequency meter for proper frequency output.
4. Keep a check on the amperage in each leg of the line.
5. Keep an eye on the charging ammeter for correct charging of the battery.
6. Watch the water temperature gage to see that the engine is not overheating.

After shutdown:

1. Fill gasoline and fuel tanks.
2. Fill radiator and check oil level.

PARALLELING THE ALTERNATORS

During a heavy load period you might have to bring the other main generator onto the line. Don't just start the engine up and then throw the main switch. If you do, you're liable to see the unit rise about 10 feet off the ground. Why? Because it hasn't been SYNCHRONIZED with the generator that's already on the line.

Before the main switch of the incoming generator may be safely closed you must make sure that:

1. The output voltage of the incoming generator is equal to the bus-line voltage.
2. The frequency of the incoming generator is equal to that on the bus line.
3. The voltage of the incoming generator is in phase with the bus-line voltage.

Flipping a coin won't tell you when to close the main switch, but watching the SYNCHRONIZING LAMPS will. Synchronizing lamps are built just like ordinary light bulbs. Of course, their rated voltage must be the same as the generator output.

A lamp is placed across each terminal of the 3-pole main

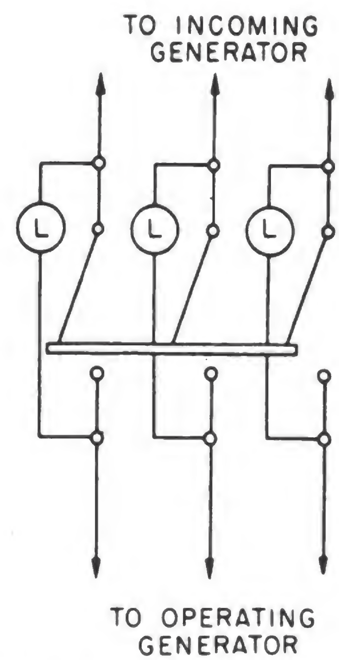


Figure 217.—Synchronizing lamp circuit.

switch (figure 217). The main switch, when closed, connects the incoming generator to the bus line. When the main switch is open, the current through each lamp will depend on the voltage across their terminals. The lamp-terminal voltage, in turn, depends on the phase difference between the incoming generator voltage and the bus-line voltage. When the incoming generator voltage and bus voltage are out of phase, the lamps will light. When the voltages are in phase, the lamps will be dark.

The two voltages are alternately going in and out of phase. Thus, as you watch the lamps, you will see them flicker. That is, they will first grow bright and then become dark. The RATE of flicker will depend on the DIFFERENCE in the frequencies of the two alternators.

Close the main switch when there is no voltage across the switch terminals. This will be the instant the lamps are DARK.

By the Numbers

Paralleling generators is easy if you follow a common sense course. You may think it's "by the numbers" but it's really the only RIGHT way to do it.

Step 1.—Start your incoming Diesel unit.

Step 2.—Adjust the voltage of the incoming unit so that it equals the voltage of the generator on the line.

Step 3.—Flip the synchronizing-lamp switch to the ON position.

Step 4.—Adjust the frequency of the incoming generator (throttle control) until the rate of flicker of the synchronizing lamps is very slow.

Step 5.—At the instant the lamps are DARK, throw the main switch to the ON position.

Here's a tip. Throwing the main switch the instant the lamps become dark might cause you to overshoot your mark. Your reaction is a lot slower than you think. You'll find that throwing the main switch the instant BEFORE the lamps grow dark will give you better synchronization.

Dividing the Load

After throwing the main switch take a look at the A.C. AMMETERS of each of the generating units. They must read an equal amount. If the readings are unequal it means that one generator is doing more work than the other.

Each generator must share an equal part of the load. To divide the load evenly, increase the speed of the generator unit which has the LOWEST current reading. Adjust the throttle knob until both a.c. ammeters read the same.

THE SYNCHROSCOPE

The synchroscope is just another means of indicating the

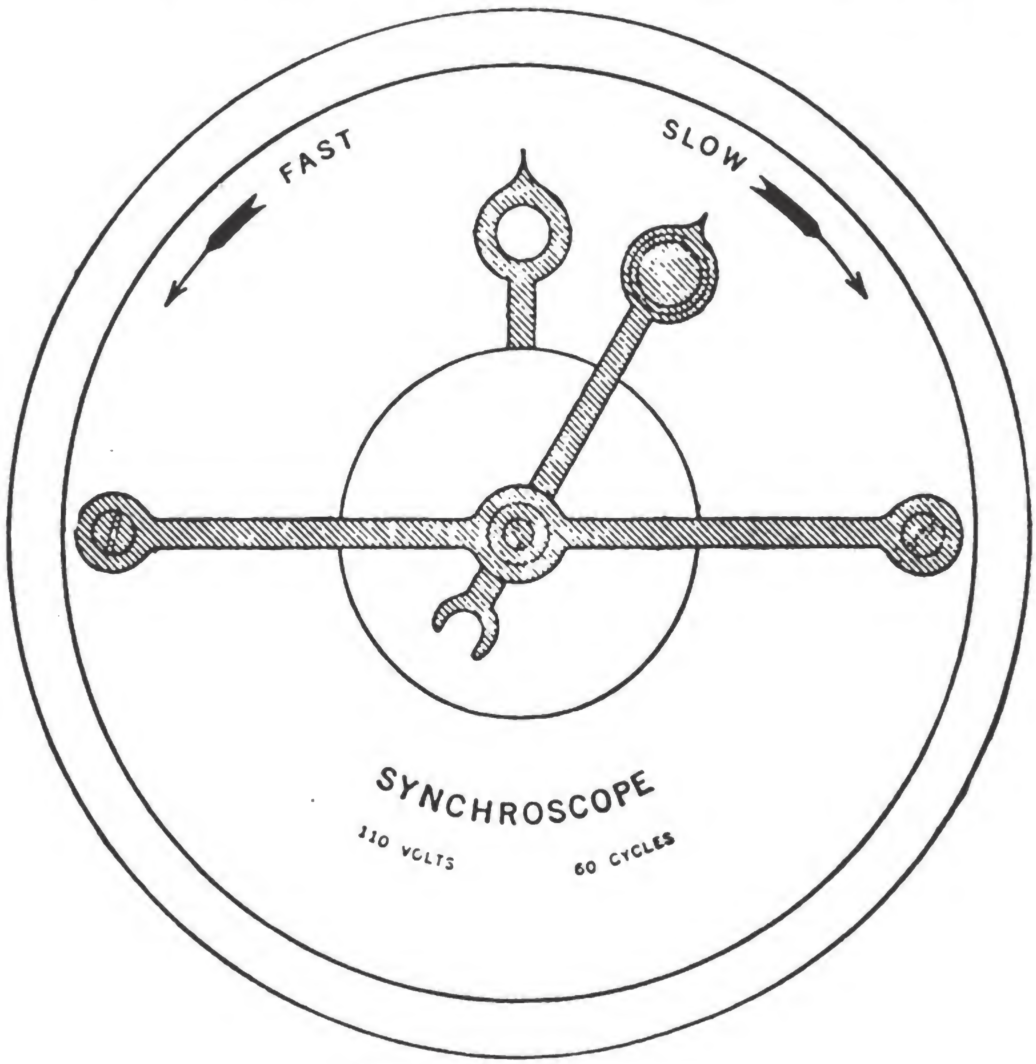


Figure 218.—Synchroscope.

point at which two alternators may be paralleled. Figure 218 shows what it looks like. That movable hand is mounted on a rotor coil which is free to turn in the field of a stationary electromagnet. The electromagnet is energized by the bus line. The rotor coil is energized by the incoming generator.

The net effect of the two magnetic fields will determine the movement of the hand. If the two generators are synchronized the hand will stay in the middle of the dial. If the hand moves to the right it indicates that the incoming generator is running too slow. If the hand rotates to the left it means that the incoming generator is running too fast.

You adjust the speed of the incoming generator until the hand comes to a standstill in the middle of the dial. At this moment the main switch should be closed.

You may find it impossible to get the hand at an exact standstill. In that case close the main switch just BEFORE the hand reaches the middle of the dial. It should be moving slowly in the fast direction.

SUMMARY

Advanced base electric-generator sets are built as complete portable units. They include the PRIME MOVER, the GENERATOR, and the SWITCHBOARD.

At the beginning, the generator sets may be spotted wherever needed. Later, central power stations are installed to serve large areas from one location.

The central power station will usually include two main generators and one emergency unit.

The output of the generators is controlled at the switchboard and collected at the bus bar. The bus bar distributes the energy to the feeder lines.

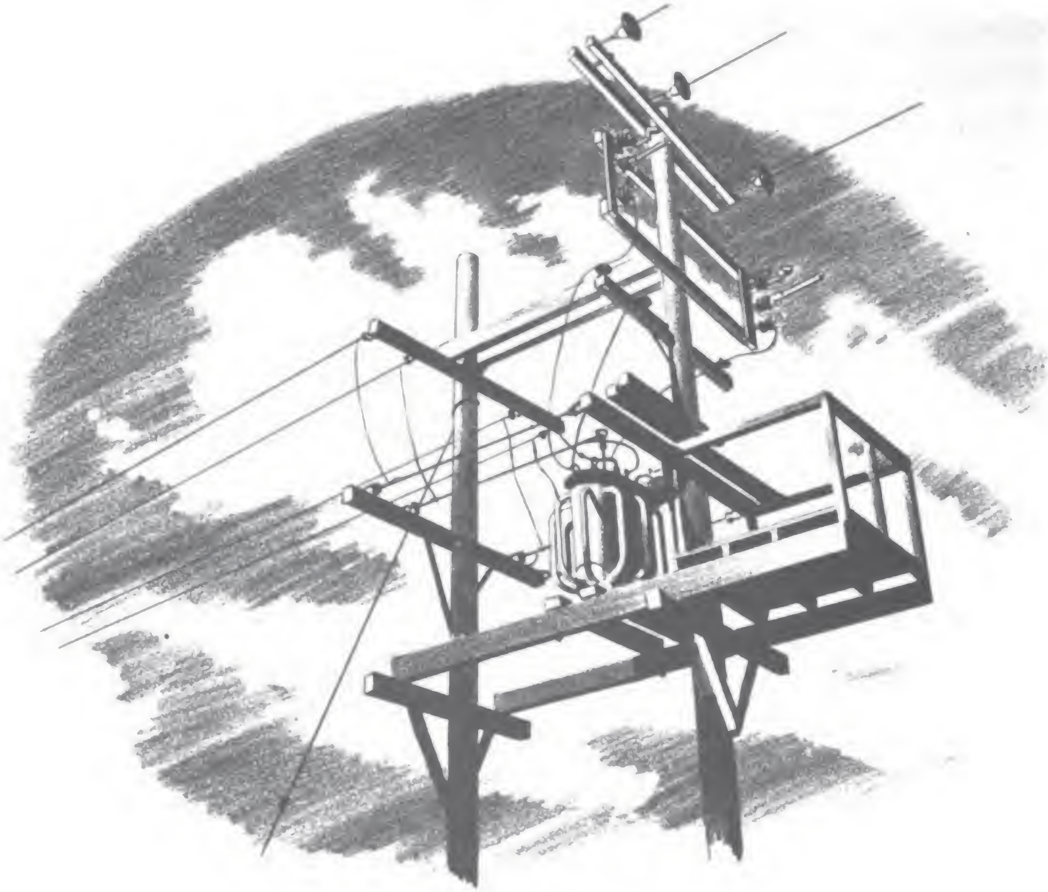
Your general maintenance of the prime mover will include cleaning the air cleaner, replacing defective spark plugs, setting proper spark-plug gap, cleaning and replacing the oil filter, replacing brushes and cleaning the commutator on starting motor and charging generator, and checking battery condition.

Your generator watch duties will include keeping an eye on generator voltage output and frequency, maintaining a log,

starting and paralleling alternators, emergency procedures, keeping oil at proper level, keeping fuel tanks full, and adding water to the cooling system.

QUIZ

1. Give three reasons for establishing a central power station rather than scattered individual generating plants.
2. Name the four strokes of the piston in the Diesel engine.
3. What two materials does an air cleaner use to filter dust from the incoming air?
4. Why is it important to stay clear of the exhaust pipe?
5. What is the purpose of the radiator thermostat?
6. What is the assembly called which sprays the fuel oil into the cylinder?
7. What size screen would you use to strain the fuel oil when filling the tank?
8. Why is it important to keep a full fuel tank?
9. Why are gasoline-driven units better than Diesels for portable generators?
10. Name five essential parts included in all gasoline-motor ignition systems equipped with starters.
11. Which electrode is always bent on the spark plug to adjust the gap?
12. What is used to clean the contact points of the regulator relays?
13. When using synchronizing lamps to parallel alternators, when is the main switch closed?
14. When using the synchroscope, when is the main switch closed?
15. How is the alternator's frequency increased so that it may be paralleled to other alternators?



CHAPTER 8

DISTRIBUTING ELECTRIC POWER

THE PROBLEM

An advanced base needs electric power. There's no argument about that. The lights in the LIVING QUARTERS, the refrigerator unit in the MESS HALL, the runway lights along the AIRSTRIP, the motors over at the SAWMILL, and the lathes in the MOTOR POOL repair shop are but a few of the many devices which are electrically operated.

"O.K.", you might say, "what's the problem? There's the generating station that produces the electric power. Over here's the equipment that needs the power. Just string a line between the two and you're all set."

Sounds good—but it won't work. And here's the reason why. All of the equipment ISN'T IN ONE SPOT. Living quarters, mess

hall, airstrip, sawmill, and motor pool are scattered over the area. Stringing a continuous line to each of these spots just isn't common sense. Besides wasting a lot of valuable wire, you probably couldn't find a conductor large enough to carry all the current.

SOLVING THE PROBLEM

The DISTRIBUTION SYSTEM is the answer to the problem of carrying current between the generating station and widely scattered points.

To understand how the distribution system works, set yourself about 1,000 feet above an advance-base area. You won't need wings. Just look at the bird's-eye view of the a.c. distribution system in figure 219. Notice that the generating station

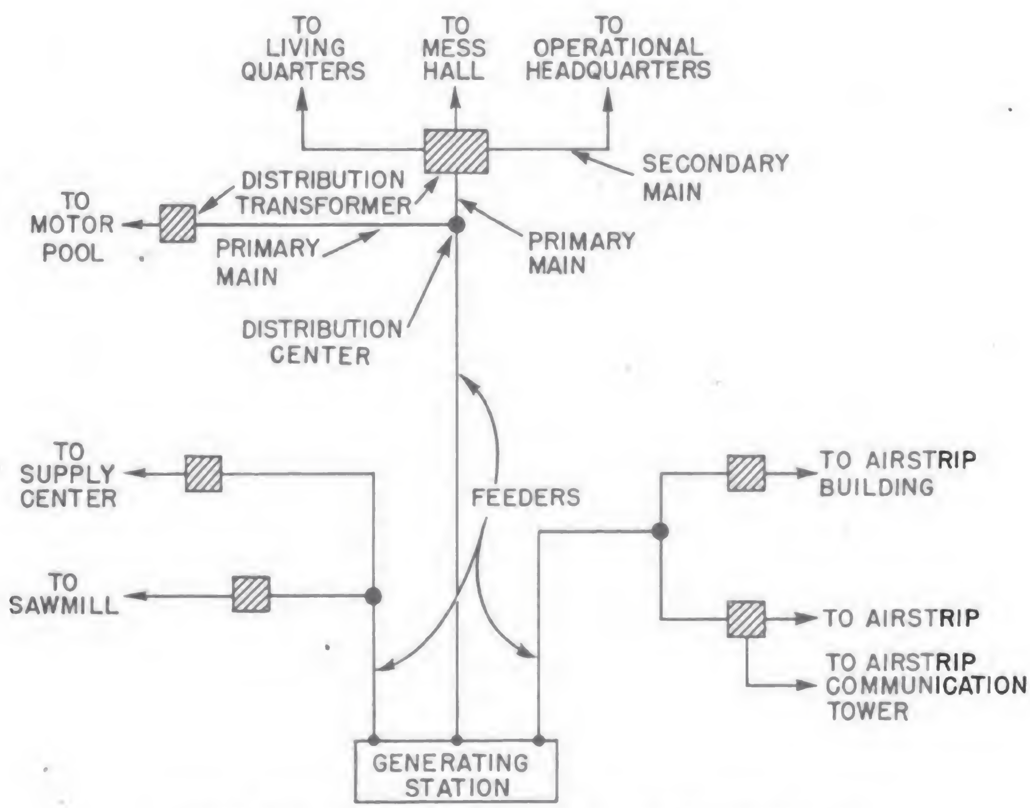


Figure 219.—Bird's-eye view of a distribution system.

is the focal point of the whole system. On the right are the airstrip, communication tower, and other buildings. Up towards

the center are the living quarters, mess hall, operational headquarters, and motor pool. The sawmill and supply center are located way over to the left.

Each one of these areas is fed by a SEPARATE line from the generating station. These lines, which start from the generating station, are called FEEDERS. They carry the voltage produced by the generators.

Now take a look at the central area in figure 219. Notice that the motor pool is some distance to the left of the living quarters, mess hall, and the operational headquarters. Getting voltage over to both sections means splitting the feeder into two PRIMARY MAINS. This is done at the DISTRIBUTION CENTER.

There are a couple of points which should be brought to your attention at this time. Point No. 1: the voltage on the feeder line is the same as the voltage on the primary mains. That means there is no change of voltage at the distribution center. No. 2: there is no tapping of the feeder line between the generating station and the distribution center.

Each primary main is further subdivided into a number of SECONDARY MAINS. The secondary mains distribute the voltage to the electrical equipment scattered over the area. In some cases, the primary voltage may be higher than that needed for proper operation of the electrical equipment. The change-over from high to low voltage is made right at the point where the secondary mains split off from the primary mains. The step-down in voltage is accomplished by a DISTRIBUTION TRANSFORMER.

BOILING IT DOWN

Here's what the distribution system boils down to:

1. Feeder lines distribute the generating-station voltage to the distribution centers in each area.
2. Primary mains distribute the feeder-line voltage from the distribution center to each section of the area.
3. Distribution transformers (if needed) step-down the voltage of the primary main.
4. Secondary mains distribute the voltage to the electrical equipment in each section of the area.

When you speak about the voltage on the primary mains refer to it as the PRIMARY VOLTAGE. The voltage on the secondary mains is termed the SECONDARY VOLTAGE.

TYPES OF DISTRIBUTION SYSTEMS

Someone might ask what type of distribution system is being used in your area. You should know the answer, so hustle over to the generating station and take a look at the feeder lines. If you see that each feeder is made up of three wires then you know that you have a THREE-WIRE DISTRIBUTION SYSTEM. On the other hand, a four-wire feeder means a FOUR-WIRE DISTRIBUTION SYSTEM.

Now just what determines whether a distribution system will be three-wire or four-wire? You get the answer to that question by stepping inside the generating station and examining the main generators.

The alternators which supply the power to the feeder lines are of the three-phase type. That is, they have three stator coils set 120 electrical degrees apart on the stator core. The output of these coils is connected, through the switchboard and bus bar, to the feeder lines. Therefore, the arrangement of the stator coils will determine the number of wires in the feeders.

Delta-Connected Alternators

In some alternators the three stator coils are arranged in a DELTA fashion. A simple drawing of this connection is shown in figure 220. The term delta is used to describe this winding because the coils form a triangle which looks like the Greek letter, delta (Δ..).

Here's the scoop on how the output voltage is taken from the stator coils. Notice in figure 220 that a line is tied to each corner of the delta stator. Any two of the three lines are directly across the ends of one of the three coils. For example, lines 1 and 2 are tied to the ends of coil *A*. A voltmeter reading between lines 1 and 2 would indicate the single-phase voltage developed in coil *A*. Thus, if the alternator rated voltage was 220 volts, you would read 220 volts on the voltmeter.

The voltage across lines 2 and 3 and lines 1 and 3 would also be 220 volts. These are single-phase voltages. But don't forget

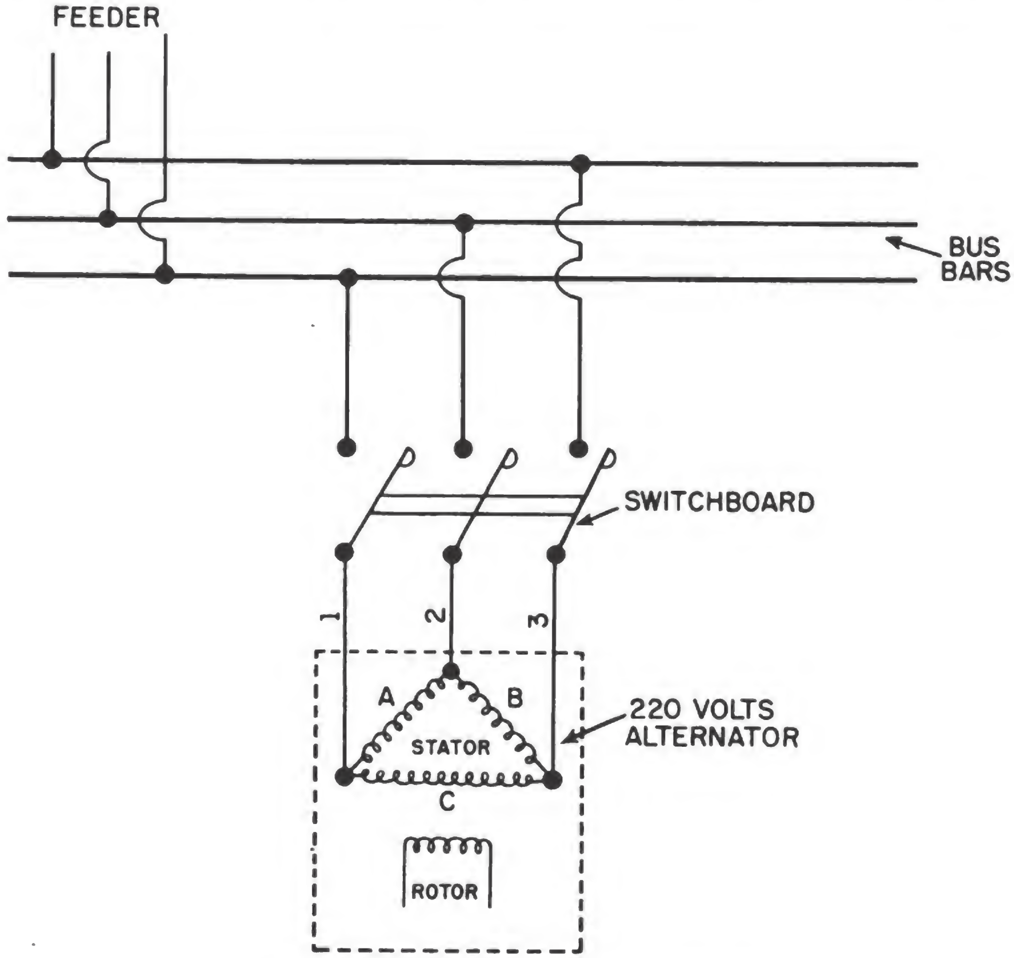


Figure 220.—Delta-connected alternator.

that you can obtain a three-phase voltage by taking the output from all three leads at the same time.

Y-Connected Alternators

How can you get four output wires from three stator coils? That's easy. Just arrange the coils as shown in figure 221. This is called a *Y* or STAR connection.

One end of each coil is connected to a common or NEUTRAL POINT. The line wires are tied to the free ends of the coils. A fourth wire, called the neutral wire, is connected to the neutral point.

Just how is this *Y* stator different from the delta stator?

Well, first take a look at lines 1 and 2. Notice that they are connected across both coils A AND C. This means that the voltage between lines 1 and 2 is the vector sum of the voltages developed in coils *A* and *C*. The same thing applies to lines 2 and 3, and 1 and 3.

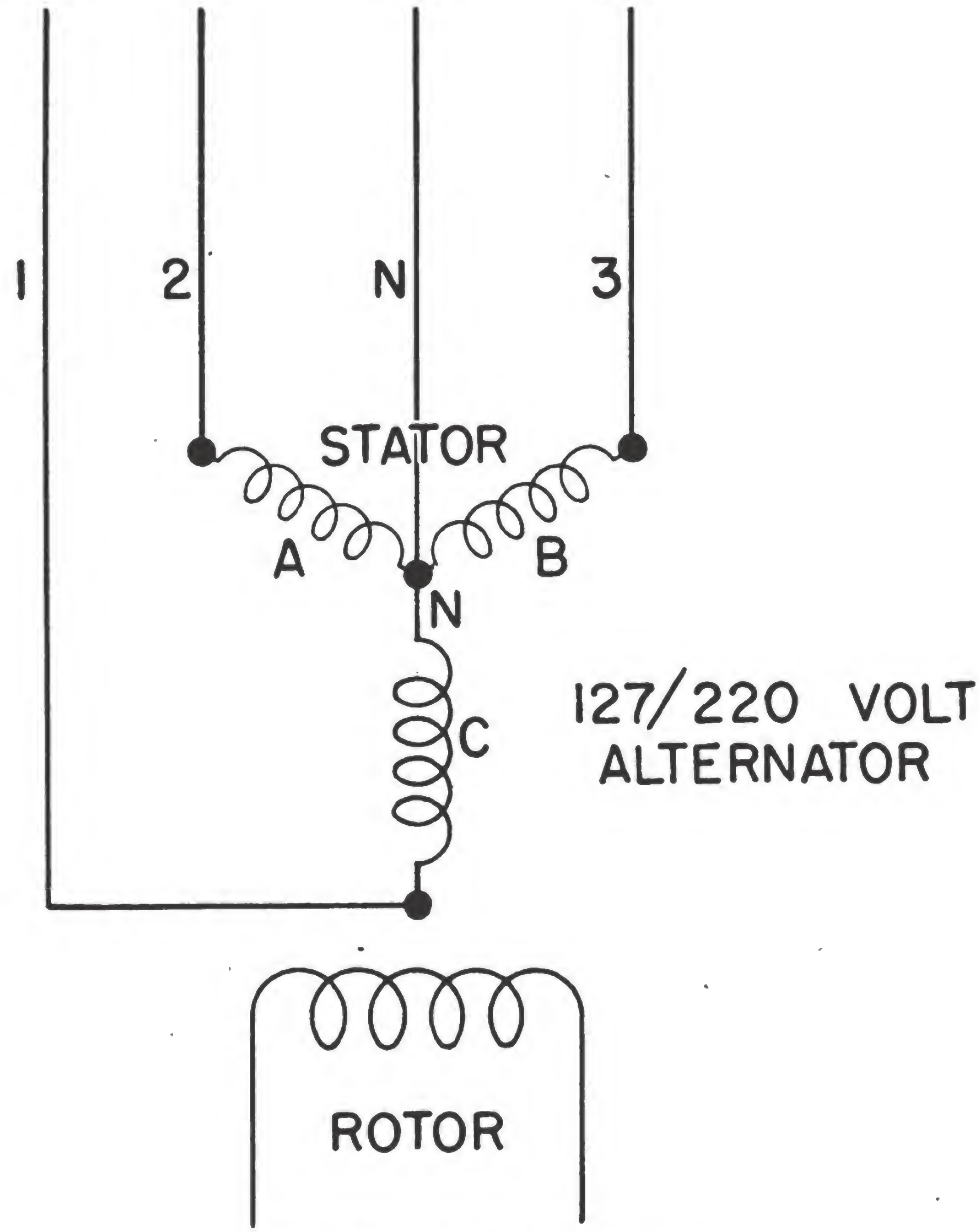


Figure 221.—Y-connected alternator.

Now take a look at the neutral wire. You can see that the voltage between the neutral wire and any one of the three leads is equal to the voltage developed in any one stator coil. A voltmeter placed between line 2 and the neutral wire, for example, would indicate the voltage developed in coil A.

Alternators which are Y-connected will have TWO voltage ratings. For example, the alternator of figure 221 has a voltage rating of 127/220. This tells you that each stator coil will develop a single-phase voltage of 127 volts. To obtain this voltage just tap a line to the neutral wire and any one of the other three wires. The 220-volt rating indicates the voltage developed across any two of the three stator coils. You obtain this voltage by tapping a line to any two of the three main leads.

You can always figure out what the voltage will be between any two main leads if you know the voltage between the neutral wire and a main lead. Just multiply the neutral-wire voltage by $\sqrt{3}$ or 1.73. You can check this out by multiplying 127 volt times the $\sqrt{3}$. The product is 220 volts.

Three-Wire Distribution

In figure 219 you were perched high enough to get a good bird's-eye view of a distribution system. A bird's-eye view, however, will only give you a general plan. To see all the details you'll have to get your feet on the ground. Figure 222 does all the work for you. It's a close-up view of the central feeder line shown in figure 219—the one that feeds power to the living quarters, mess hall, operational headquarters, and motor pool.

This particular system is a three-wire 220-volt per phase set-up. Starting from the generating station, the three-wire feeder is carried overhead to the distribution center. At the distribution center the feeder splits into two primary mains. One primary main swings off to the right, the other continues toward the center section of the area.

The motor pool primary main is strung over to a pole on which a distribution transformer is hung. The primary of the transformer is connected, through fuses, to two of the feeder lines. This brings single phase, 220-volts into the distribution-

transformer primary. The distribution transformer steps the 220 volts down to 110 volts on the secondary.

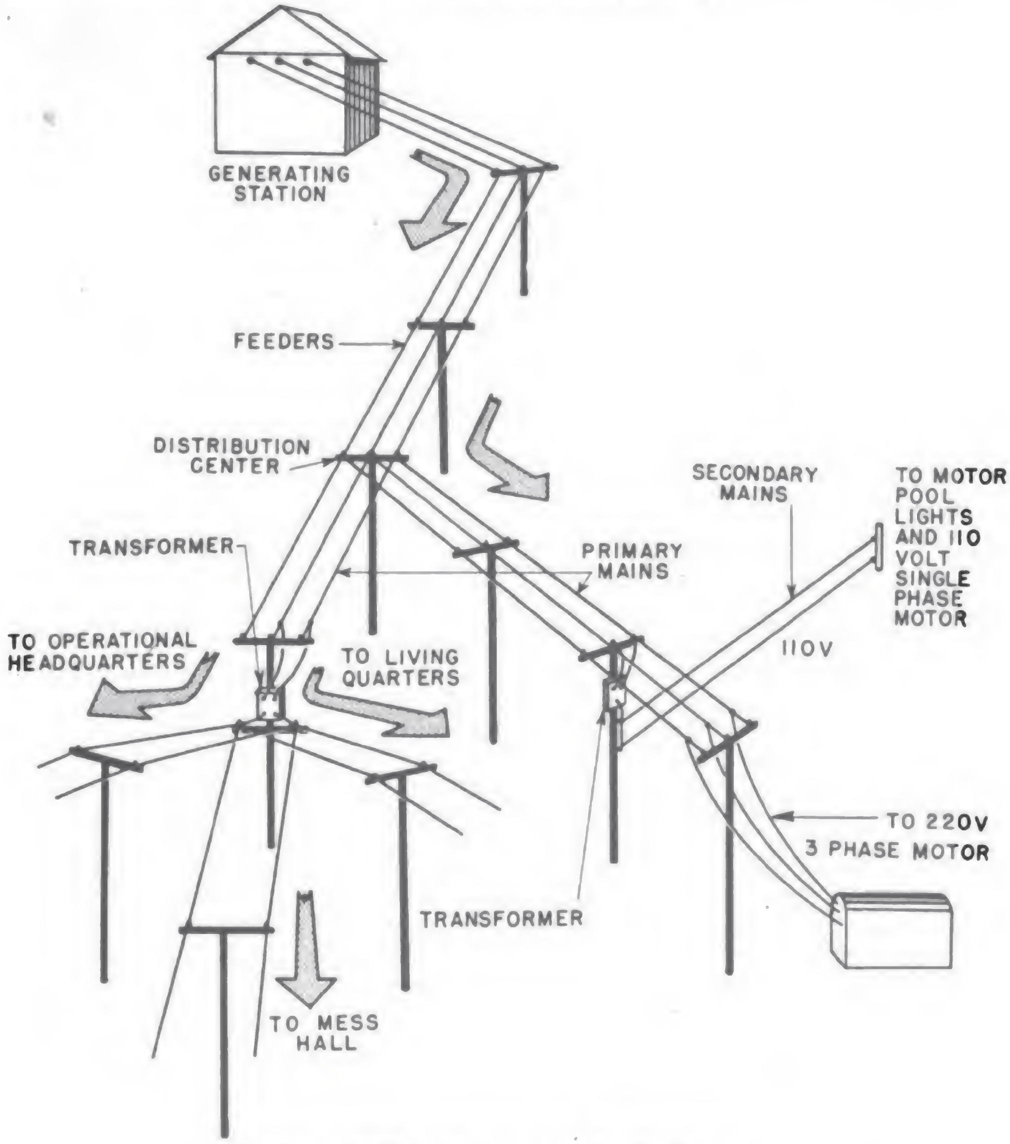


Figure 222.—Three-wire distribution.

The transformer secondary is connected to the secondary mains. The secondary mains are strung UNDERNEATH the primary mains. Lines are then tapped off the secondary mains to any motor pool buildings which need 110 volts for lights or single-phase motors.

There's a 220-volt, three-phase motor in one of the motor pool repair shops. Power for this motor is obtained by tapping directly into the 220-volt, three-phase primary main.

Now let's go over to primary main which feeds the central section. Notice that it is made up of only two of the three main feeder wires. This indicates that there is no equipment in the central section that operates on three-phase power. The 220-

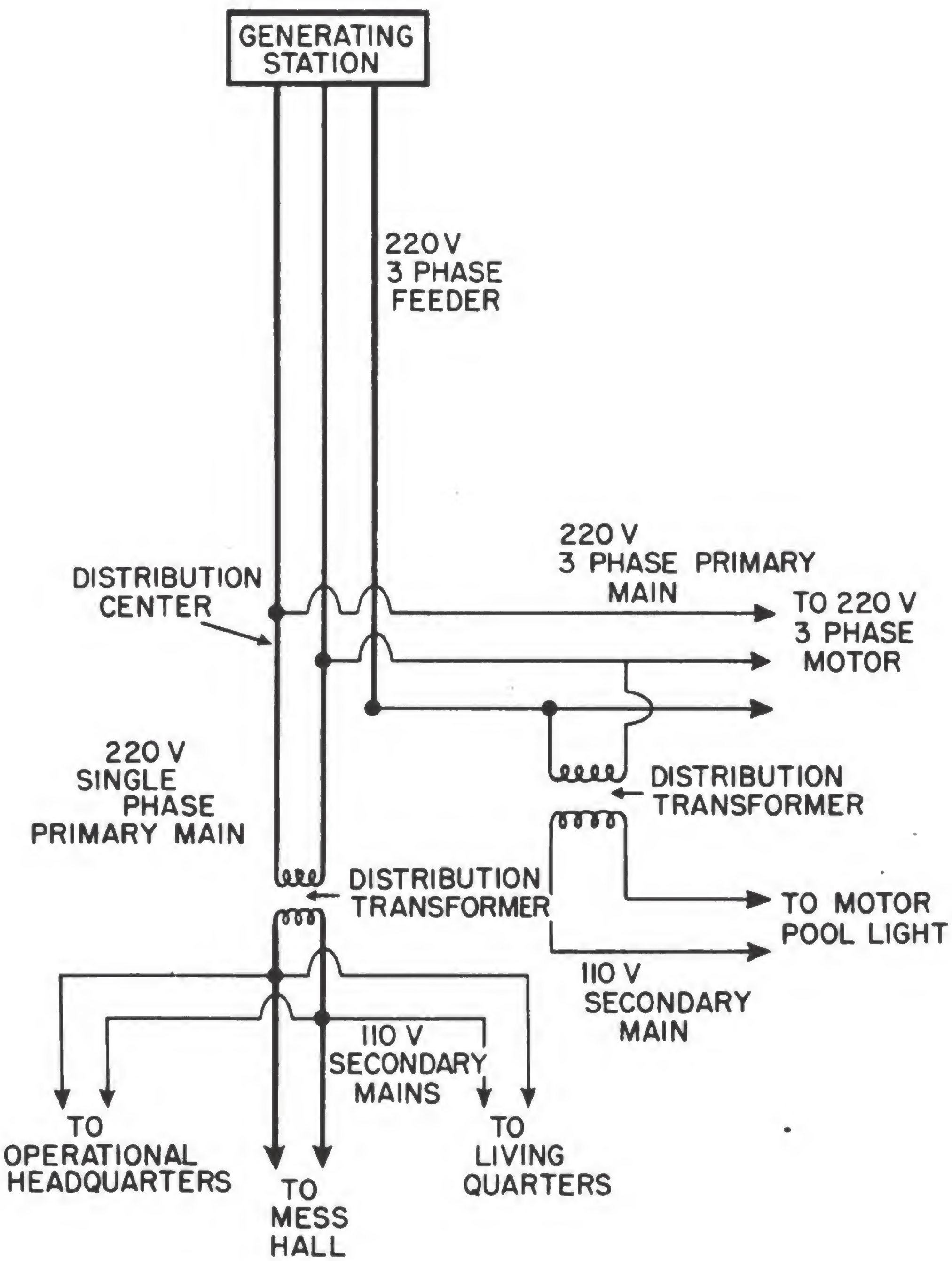


Figure 223.—Wiring diagram of three-wire system.

volt single-phase primary main is strung over to the pole which carries the distribution transformer. The transformer reduces the primary voltage to 110 volts for the secondary mains. The secondary mains distribute the 110 volts to the lights in the living quarters, the lights and refrigerator unit in the mess hall, and the lights and equipment in the operational headquarters.

If any of the connections of the three-wire system in figure 222 are not too clear, look at figure 223. It is a wiring diagram of the same system. You can see exactly how the single-phase transformers are tapped into the primary mains.

Four-Wire Distribution

Replace the three-wire system of figure 222 with a four-wire

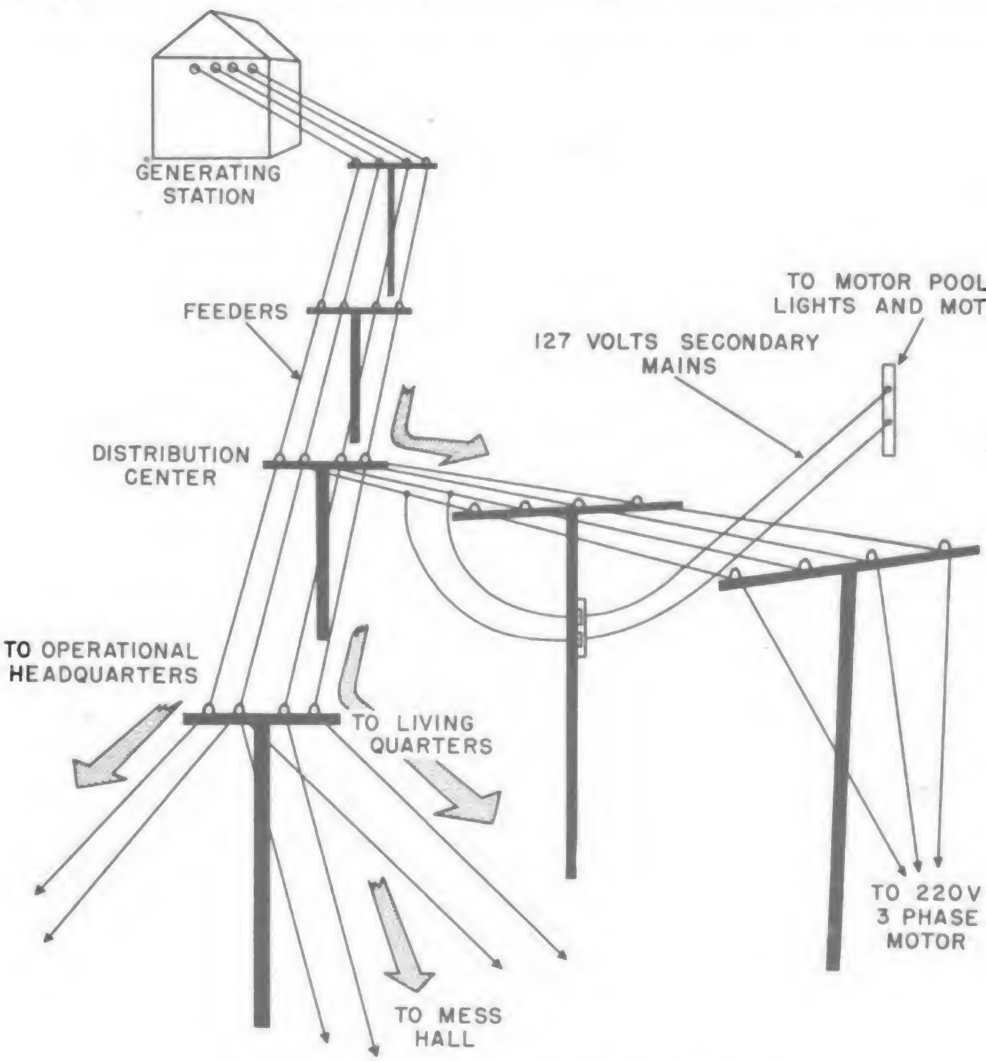


Figure. 224—Four-wire distribution system.

system and you get the results shown in figure 224. The alternator in the generating station is Y-connected and rated at 127/220 volts.

The four-wire feeder (three main wires and one neutral wire) is strung overhead to the distribution center. Here the feeder splits into a four-wire primary main which travels over to the motor pool section, and a four-wire primary which is sent to the central section.

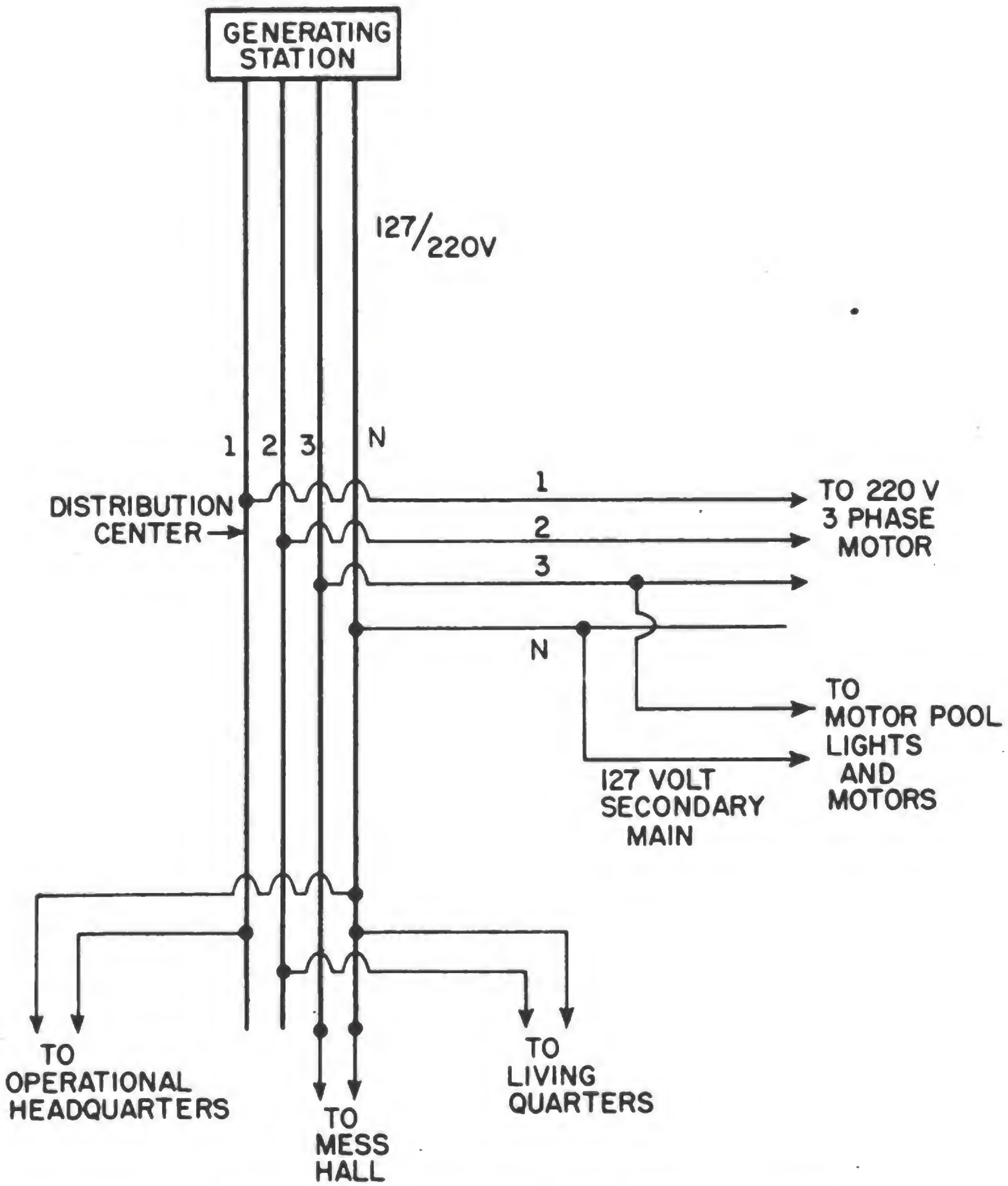


Figure 225.—Wiring diagram of four-wire system.

Since you already have 127 volts single-phase between neutral and line, it won't be necessary to use distribution transformers. Lights and single-phase motors are supplied directly from the primary main. The load on the primary main is evenly distributed by using the neutral wire and alternate lines. The three-phase motor is supplied with power from the three main wires.

You can use figure 225 if you need a clearer picture of the connections.

DISTRIBUTION-TRANSFORMER PRINCIPLES

Distribution transformers are electrical devices that lower (step-down) a. c. voltages. The essential parts of a distribution transformer are shown in figure 226.

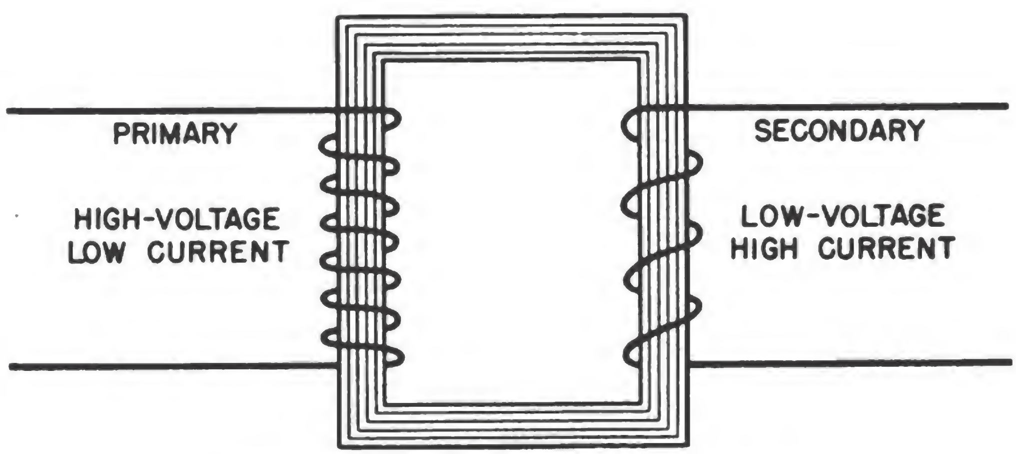


Figure 226.—Elementary distribution transformer.

A laminated iron core forms a closed magnetic circuit. On one leg of the core is placed a coil, formed of fine wire. It is called the PRIMARY WINDING and is connected to the primary mains. On the other leg of the core is placed a coil, made of a few turns of heavy wire. It is called the SECONDARY WINDING and is connected to the secondary mains.

The amount of step-down in voltage depends on the number of turns in the primary coil compared to the number of turns in the secondary coil. Suppose that the primary main voltage is 220 volts and you want a secondary voltage of 110 volts. You

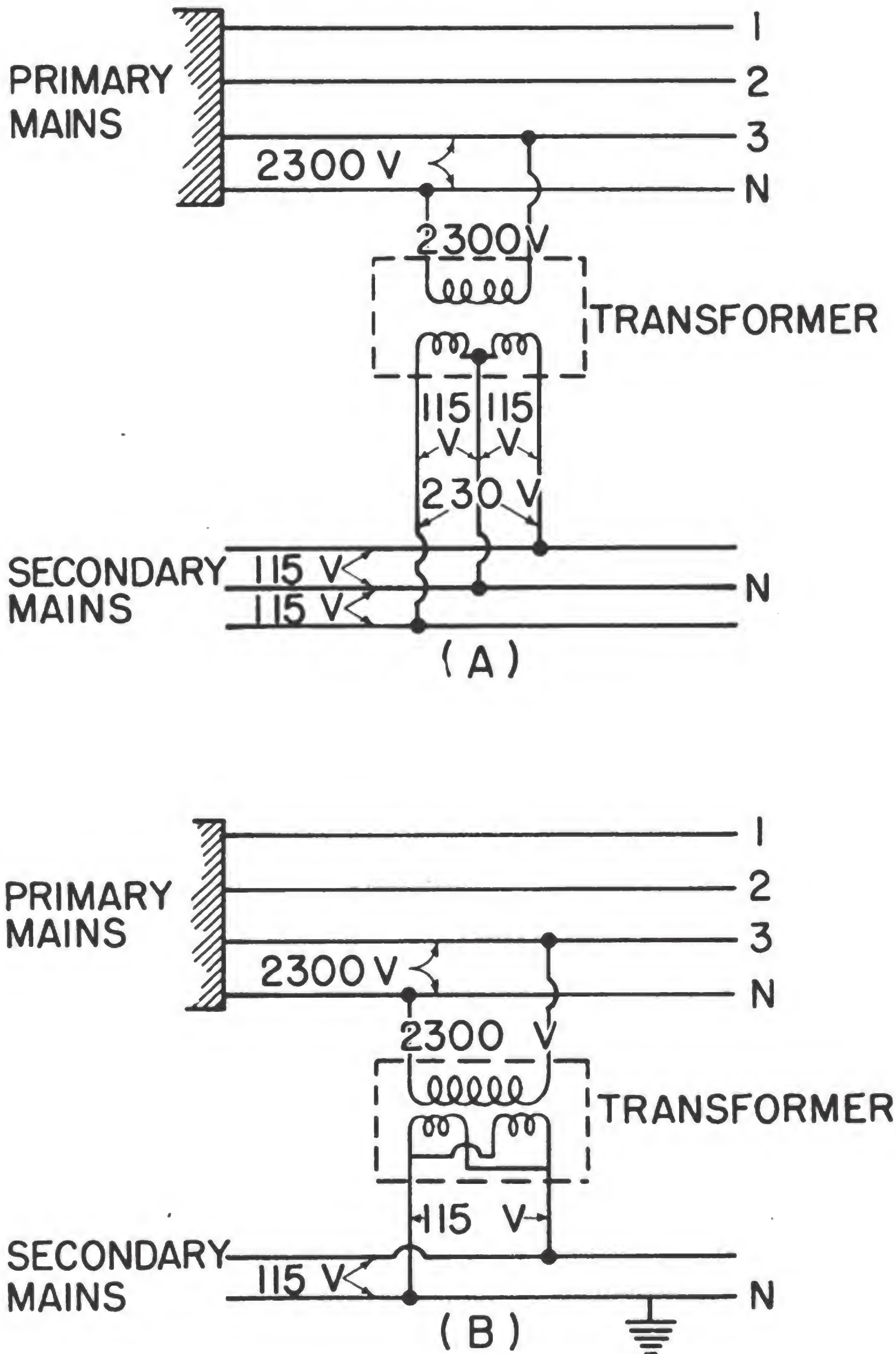


Figure 227.—Single-phase transformer connections.

would use a transformer whose secondary coil has half as many turns as the primary. This is called a step-down ratio of 2 to 1.

In almost all cases the primary voltage will be higher than 220 volts. For example, a four-wire primary main serving a large area might carry 2300 volts between line and neutral. To step this high voltage down, it will be necessary to use a transformer with a greater step-down ratio. The ratio will depend on the required amount of secondary voltage.

The single-phase distribution transformers which are used on 2300-volt primary mains are usually constructed with two secondary windings. It's just like having two separate transformers using the same primary winding. The secondary coils may be connected in series or parallel. It all depends on what voltage and current output you need for the secondary mains.

Figure 227 shows how a single-phase distribution transformer is connected to a 2300/4160-volt four-wire primary main. The primary winding is energized with 2300 volts by tying the primary between neutral and line. The primary coil is wound with 800 turns, while each secondary has 40 turns. This is a step-down ratio of 20 to 1, which means that each secondary will have an induced voltage equal to 1/20 of 2300, or 115 volts.

In view *A* of figure 227 the secondary windings are connected in series. The voltage output of this arrangement is 230 volts. Of course, the current is halved. Notice the three leads which are tapped from the secondary winding and connected to the secondary mains. This set-up produces a THREE-WIRE SINGLE-PHASE SECONDARY MAIN. What's the advantage? Well, it allows you to obtain 230 volts single-phase and 115 volts single-phase from the same secondary main.

In view *B* the secondary windings are in parallel. The output is only 115 volts, but you can obtain twice the current drain. This arrangement is used for TWO-WIRE SINGLE-PHASE secondary mains serving areas that require only 115 volts single-phase.

DISTRIBUTION-TRANSFORMER CONSTRUCTION

Distribution transformers aren't built as simple as the one in figure 226. Actually, there are four different ways of arranging

the primary and secondary coils on the laminated iron coil as shown in figure 228.

The CORE type in view A is used in most of the high voltage transformers. Each leg of the core contains a primary and secondary winding.

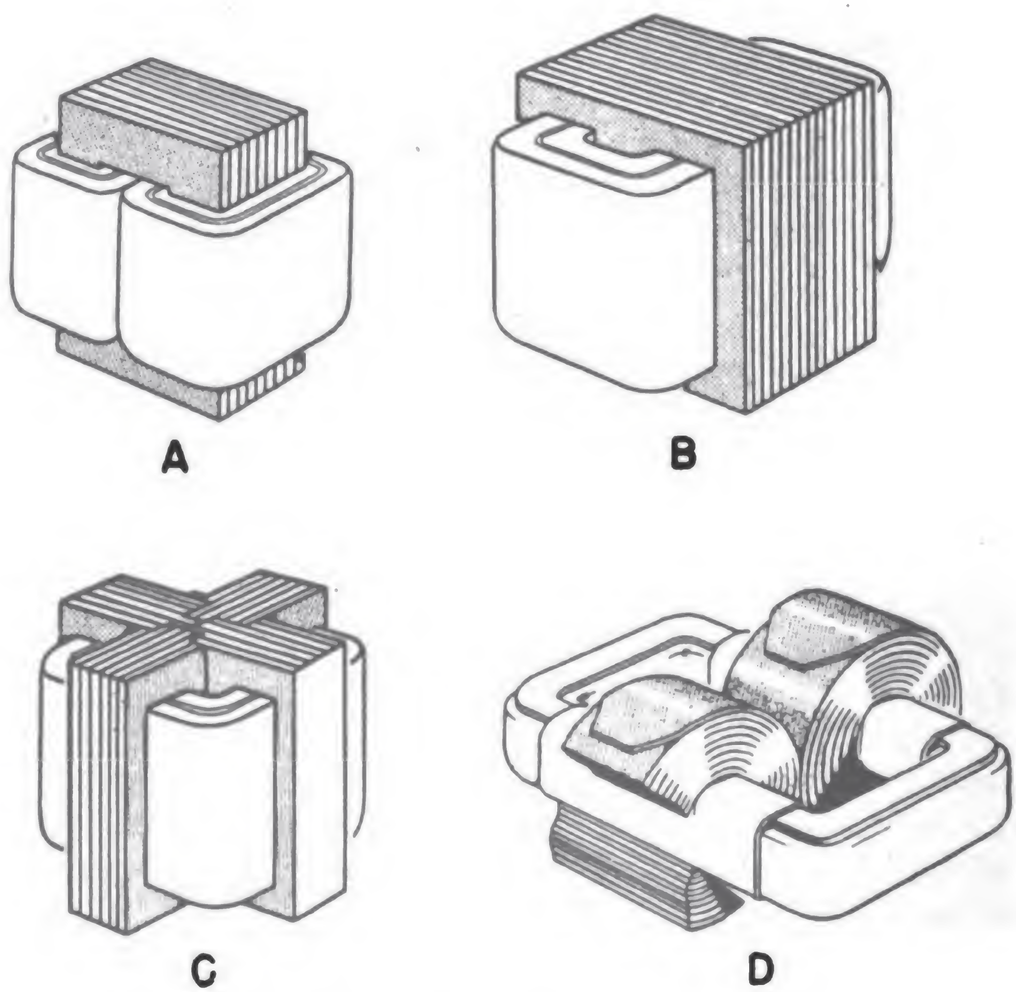


Figure 228.—Types of transformer cores.

Add a middle leg to the core type, wind the primary and secondary coils around it, and you come up with the SHELL type shown in view B. Heavy current loads require the use of this type of transformer.

The DISTRIBUTED or CRUCIFORM type (view C) is a combina-

tion of both core and shell. It has some of the advantages of each simple type.

In the WOUND–CORE type a ribbon of sheet steel is wound in a spiral around the coil. The result is pictured in view *D*. This type of winding finds its greatest use in low-voltage distribution transformers.

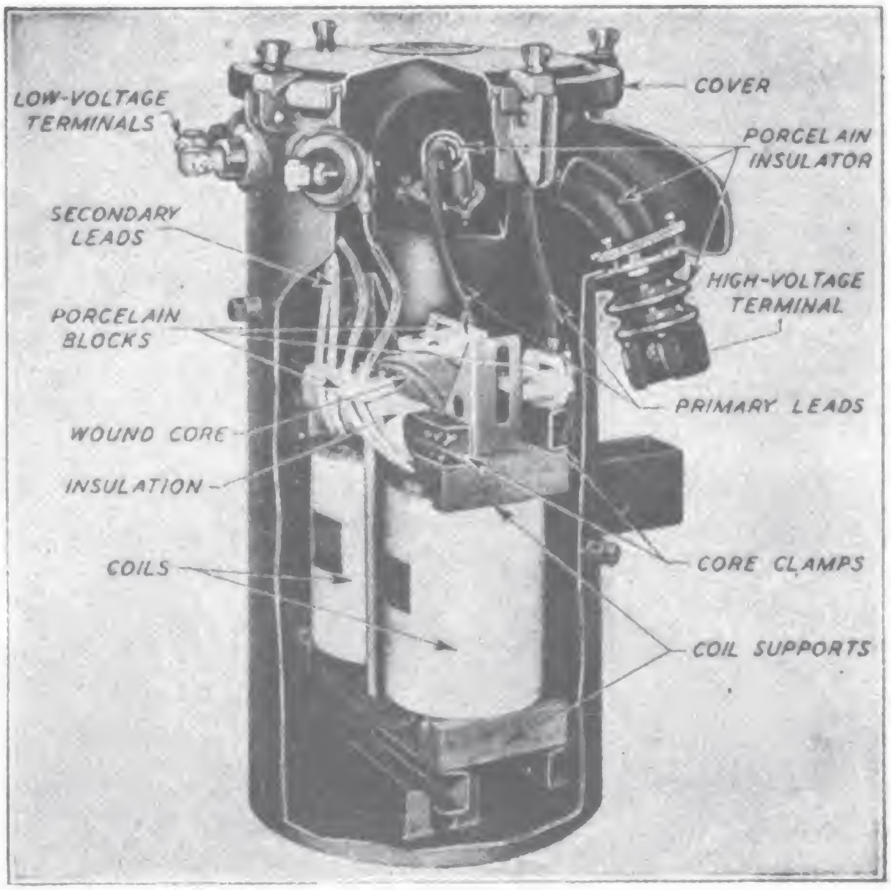


Figure 229.—Cutaway view of a distribution transformer.

Mounting the distribution transformer, that is, just the core and windings, on the pole without any protection is inviting trouble—but quick. That's why you'll find the transformer placed inside a metal case as shown in figure 229. The secondary leads connect to three low-voltage terminals. The primary leads are tied to two high-voltage terminals.

You can usually pick out the high-voltage terminals from the low-voltage terminals. Just check the porcelain bushings (insulators). The large bushings indicate the high-voltage terminals and the smaller bushings the low-voltage terminals.

A voltage transformer has no moving parts. Power is transferred from primary to secondary by means of changing magnetic fields. This makes the transformer a pretty efficient machine. Of course, it can't be 100 percent efficient. The primary and secondary windings will offer resistance to current

Figure 230.—Single-phase transformer with corrugated tank.

flow. And there is also a small amount of power loss in the iron core.

Current bucking resistance always produces the same result—HEAT. If the transformer is to operate properly, this heat must be removed as quickly as it forms. In the small, low-voltage distribution transformers, only a small amount of heat is developed. The air INSIDE the metal case transfers the heat over to the side of the container. The cooling air on the outside takes it from there.

In the larger distribution transformers, heat is formed too fast to be conducted away by air inside the container. So you can expect to find the large transformer containers filled with oil. Oil is a better conductor of heat than air. It will transfer the heat much faster from transformer to container wall.

Some transformer-container walls are corrugated. This increases the cooling-surface area from which the heat can radiate. An oil-filled single-phase distribution transformer with corrugated tank is shown in figure 230. If transformer repairs are necessary, the oil is drained through the valve outlet at the bottom of the tank.

THREE-PHASE TRANSFORMERS

You're not finished with transformers. So far, all you've studied is the single-phase type. A single-phase transformer, you'll remember, has only one primary winding. Thus, it can change the voltage of just one phase of a three-phase line. Its output can only be used to operate single-phase equipment.

Now, if the alternators in the generating station produce the same three-phase voltage that's required to run the equipment, there is no problem. All you have to do is tie your three-phase equipment directly to the primary mains. But things don't always work out that easily. Some advanced bases are quite large. That means more buildings and more equipment to serve, usually at a greater distance from the generating station. High-voltage alternators must be used. If a three-wire system is employed, the voltage between lines is usually 2300 volts. A

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four-wire system will have 2300 volts from neutral to line and 4000 volts (2300 x $\sqrt{3}$) from line to line. The two systems are shown in figure 231.

A 2300-volt three-phase line and a 230-volt three-phase motor will get along swell—if you use a THREE-PHASE TRANSFORMER between them. The three-phase transformer isn't anything out of the ordinary. It's just a device you have to use whenever you change three-phase voltage from one value to another.

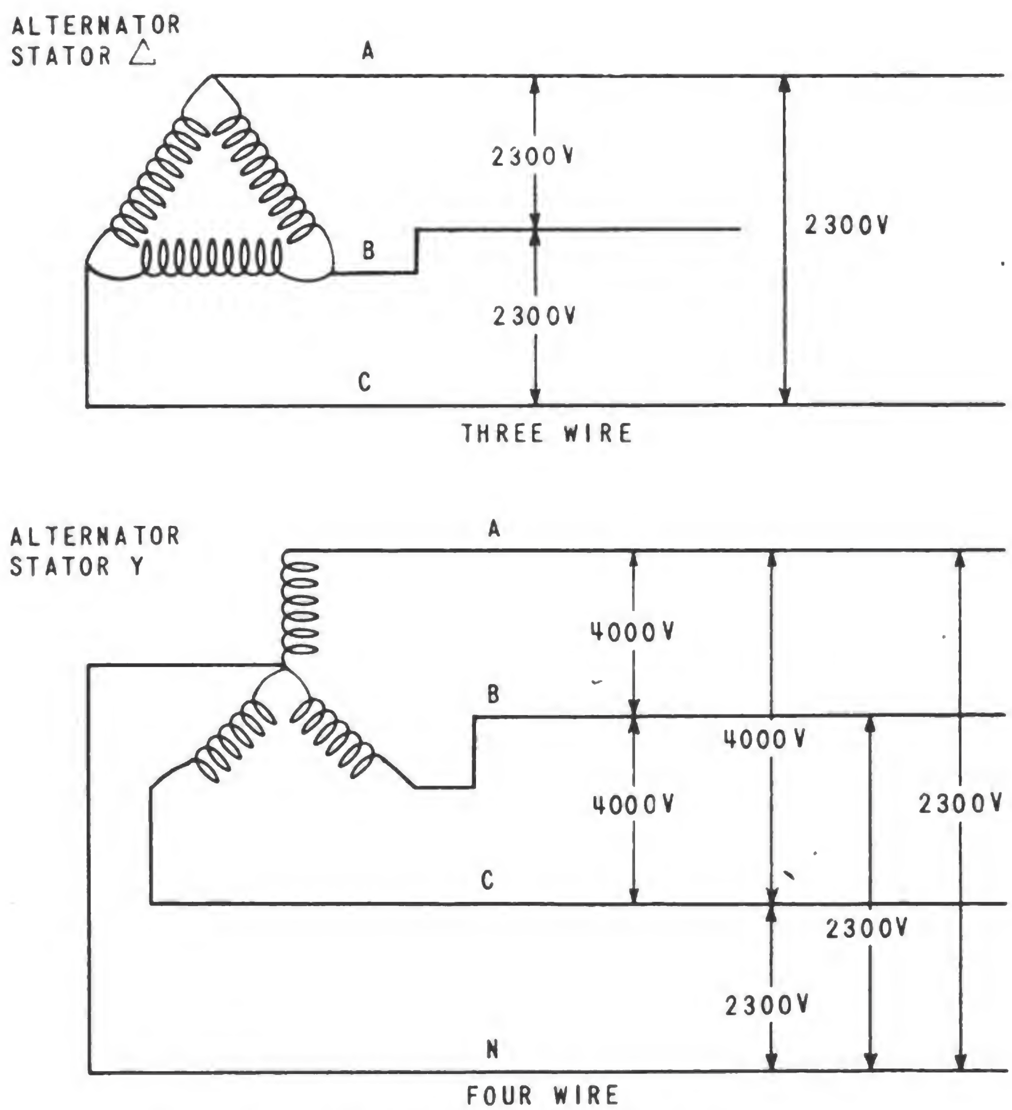


Figure 231.—High-voltage three-and four-wire systems.

You know the basic FACTS of three-phase voltage so you

should know WHAT TO EXPECT of a three-phase transformer. Here's the way they line up:

Facts about three-phase voltage:	*What to expect of a three-phase transformer:*
1. It is composed of three single-phase voltages.	1. It is a combination of three single-phase transformers (three primaries and three secondaries).
2. Each of the three voltages is 120 electrical degrees apart.	2. Each of the three primary coils will be 120 electrical degrees apart. The same applies to each of the secondary coils.
3. It is produced by coils in the alternator which are arranged either *Y* or delta.	3. The primary and secondary coils will also be arranged either *Y* or delta.

THREE-PHASE TRANSFORMER MAKE-UP

If you have three single-phase transformers with the same rating, you can connect them together to form a three-phase TRANSFORMER BANK. If the transformers are small enough you will be able to hang all three on one pole. The larger banks are mounted on a platform supported between two poles. You can see this type of construction in figure 232. Notice the connections between each transformer. That's how they are combined to form a three-phase transformer. A transformer bank may also be mounted on the ground. A fence and warning sign keep curious people alive.

Some three-phase transformers are ready-made. You'll receive them as complete units enclosed in metal cases. Each

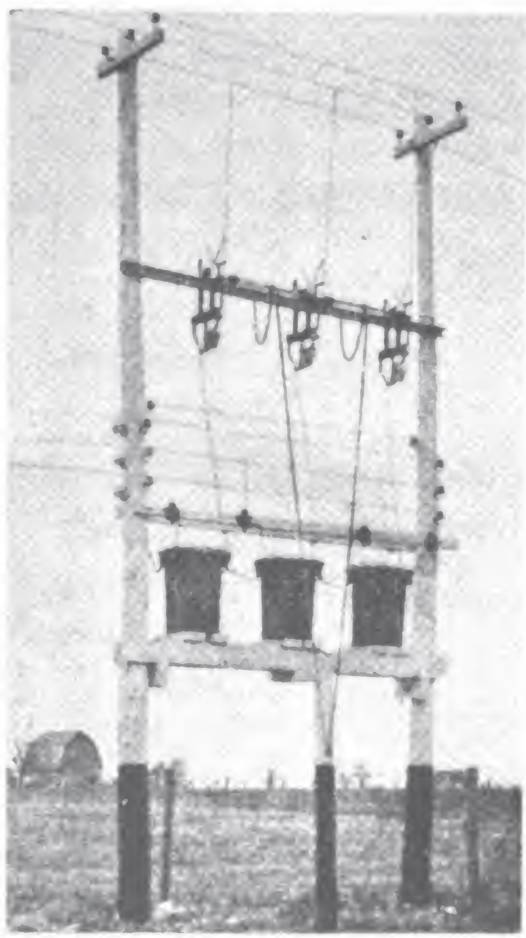


Figure 232.—Three-phase transformer bank.

transformer will be made up of three primary and three secondary windings. One iron core serves as a common path for the magnetic lines. A three-phase transformer, removed from its case, is shown in figure 233.

A ready-made three-phase transformer weighs only two-thirds as much as three single-phase transformers. Its lightness is due to the ONE iron core as compared to the three cores necessary for each single-phase transformer.

The ready-made three-phase transformer has a disadvantage, too. If a phase should burn out, it will be necessary to replace the entire transformer. On the other hand, if one of the three single-phase transformers should need repairs, it is only necessary to pull it out and put in a new one.

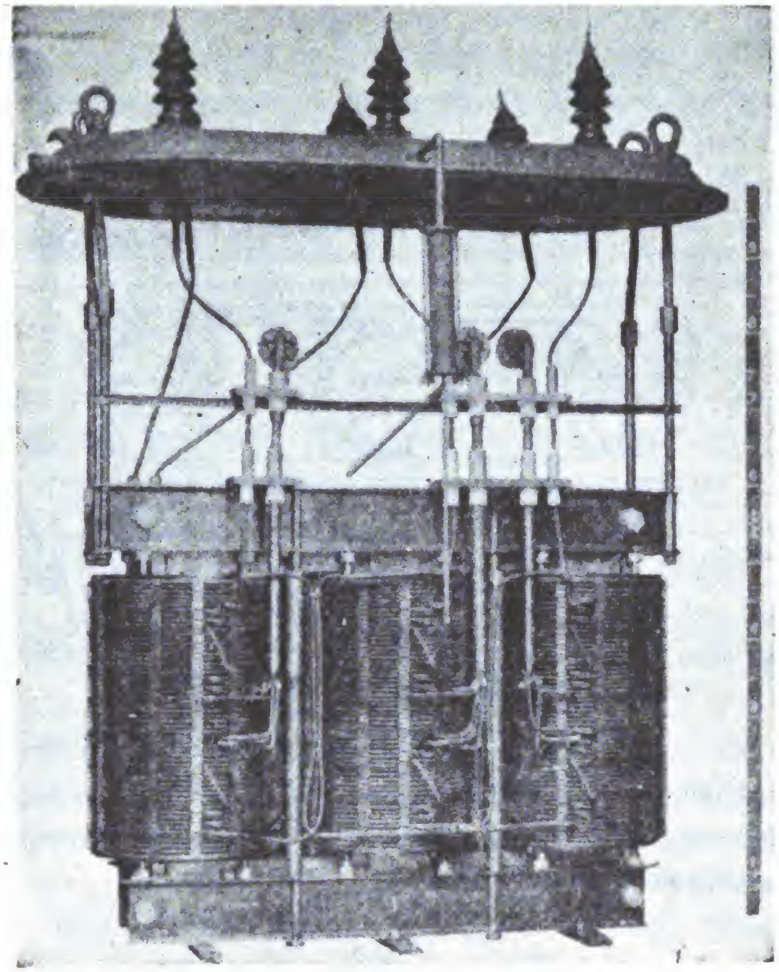


Figure 233.—Three-phase transformer.

THREE-PHASE TRANSFORMER CONNECTIONS

Delta-delta and Y-Y isn't double-talk. It's just a simple way of indicating the primary and secondary connections of a three-phase transformer. The first word or letter of the combination indicates the primary connection—the second word or letter, the secondary connection. A delta-delta, for example, tells you that both the primary and secondary windings are connected in delta. Y-Δ means Y-connected primary and delta-connected secondary.

Delta-Delta

A delta-delta transformer is shown in figure 234. The primary and secondary windings are each connected in series (delta).

The line-to-line voltage of the primary main is 2300 volts. This puts 2300 volts across each coil of the delta primary. Each primary coil has 800 turns—each corresponding secondary coil has 80 turns. Thus, each phase of the three-phase voltage will be reduced one-tenth from primary to secondary.

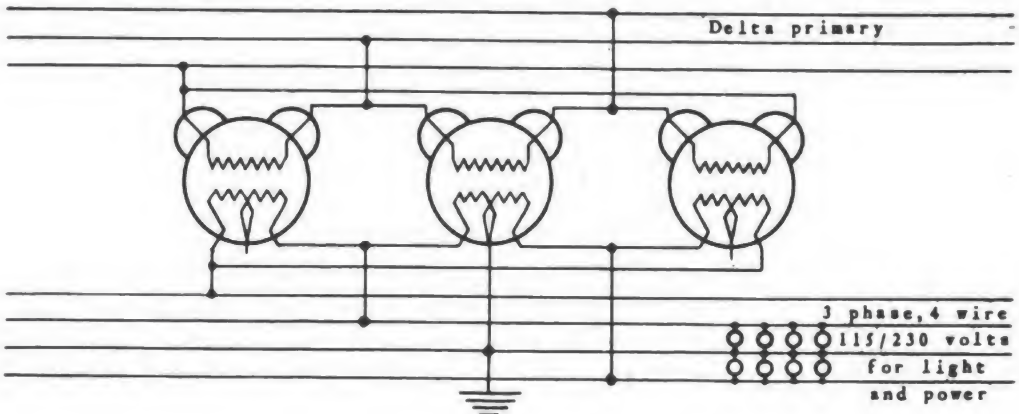


Figure 234.—Delta-delta connection.

The secondary main is three-wire, with 230 volts between lines. Any 230-volt three-phase equipment can be fed directly; 115-volt single-phase equipment, however, will need a distribution transformer.

Y-Y

A four-wire primary main will normally use a *Y*-connected primary. If the secondary is also connected *Y*, the secondary

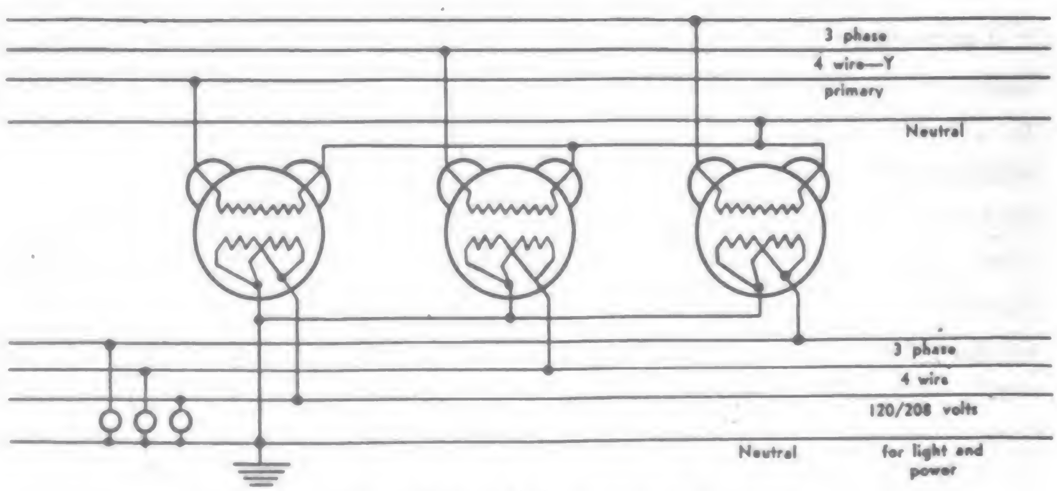


Figure 235.—Y-Y connection.

main will be four-wire. In figure 235 a 2300/4000-volt primary main is used. The turn ratio of corresponding primary and secondary coils produces a step-down in voltage to 120/208 volts.

With this set-up, you can serve both single-phase and three-phase equipment.

Delta-Y

The delta-delta transformer of figure 234 reduced the 2300-volt three-phase primary voltage to a 230-volt three-phase secondary voltage. The 230-volt three-phase secondary voltage was used to operate a 230-volt three-phase motor. Suppose that you had to supply 115 volts single-phase to a nearby lighting system. It would be necessary to ground the mid-tap of one of the transformers. This would put the entire 115-volt load on that one transformer. That's the big disadvantage of the delta-delta or *Y*-delta system.

This disadvantage is overcome with a delta-*Y* three-phase transformer. By connecting the secondary in Y, you can take care of single-phase lighting and three-phase power from the same line. And the best part of it is that the single-phase load is evenly distributed by using the neutral wire and alternate lines A delta-*Y* connection is shown in figure 236.

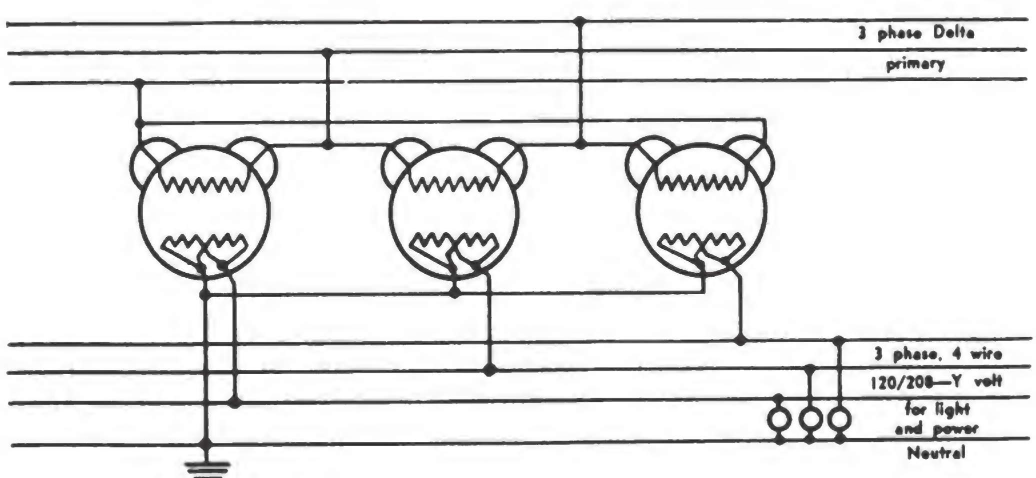


Figure 236.—Delta-Y connection.

The V Connection

A delta connection has one primary advantage over the *Y* connection. It is the ability to operate under emergency conditions. If one of the phases of a *Y*-connected transformer were to burn out, it would be necessary to shut down the whole secondary system. Operation could only be resumed after you had replaced the faulty phase.

A burned-out phase in a delta-connected transformer, however, can be taken out, repaired, and replaced without having to interrupt the secondary service. This is called a *V* or OPEN DELTA connection.

As an example, suppose you have a delta-delta transformer bank feeding power to a very important area of the advanced base. One of the single-phase transformers burns out. You remove it, leaving the two other transformers to form a *V* connection (figure 237). The *V* connection will still produce the rated three-phase voltage on the secondary.

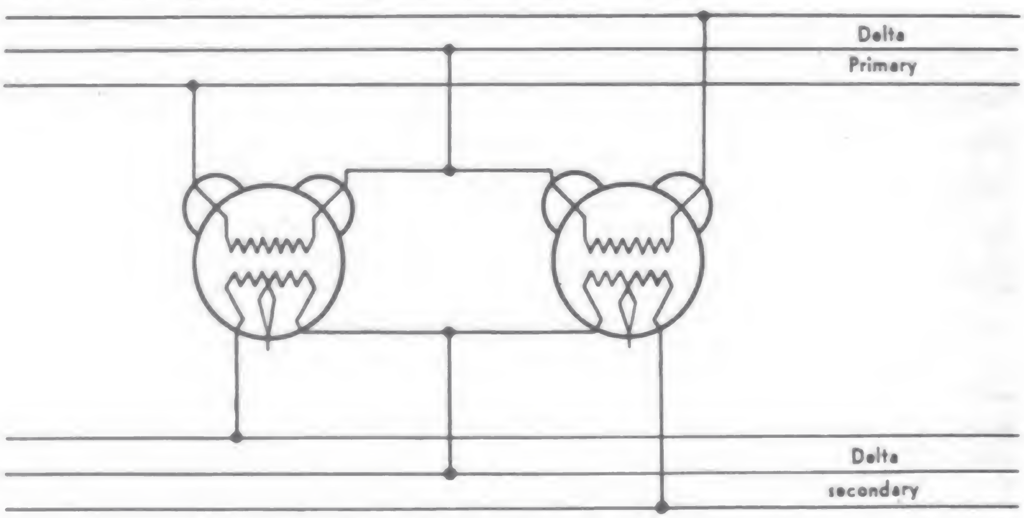


Figure 237.—V connection.

Of course the rated power load of your transformer will decrease. Originally, you had three windings to take care of the current—now you have only two. This change, from delta to *V*, will reduce the rated transformer load to 57.7 percent. If, for example, the delta transformer is rated at 30,000 volt-amperes, you will find that your *V* connection will be able to handle only 17,310 volt-amperes (30,000 x 57.7 percent).

If the power drain of the equipment operating off the secondary is less than 17,310 volt-amperes you have nothing to worry about. But if it's more, you will have to disconnect the least important equipment until the repaired transformer is restored to the bank.

GROUNDING THE SECONDARY

You probably noticed in the wiring diagrams for transformer connections, that one wire is grounded. This is a safety feature for the protection of personnel and equipment. The Navy requires that this ground wire be separate from the one installed for the lightning arrestor.

SUMMARY

Distribution systems are the answer to the problem of distributing voltages to widely scattered sections of the advanced base area.

Distribution systems consist of a feeder, distribution center, primary mains, distribution transformers (where needed), and secondary mains.

Distribution systems may use either a three-or four-wire feeder. A three-wire feeder can be tapped for one three-phase voltage and one single-phase voltage value. A four-wire feeder can be tapped for one three-phase voltage and two different single-phase voltage values.

Small distribution transformers are placed in empty metal containers for protection against dirt and moisture.

Large transformers are placed in tanks filled with oil. The oil not only acts as an insulator but also helps to cool the transformer windings.

Single-phase distribution transformers provide a reduced single-phase voltage necessary for operation of single-phase equipment.

Single-phase distribution transformers usually have two secondary windings that may be connected in series or parallel. When connected in series the voltage output is doubled and the current drain cannot exceed that of one winding. When connected in parallel the voltage output is equal to the voltage in-

duced in one winding, while the current output is doubled.

A three-wire single-phase secondary main may be tapped from a distribution transformer that has its secondary windings connected in series.

A three-wire single-phase secondary main provides two single-phase voltage values. A high voltage may be taken from the two outside lines. A low voltage may be tapped from the grounded neutral wire and either of the two outside lines.

Three-phase distribution transformers provide a reduced three-phase voltage necessary for operation of three-phase equipment.

A three-phase transformer is a combination of three single-phase transformers. The primary and secondary windings may be connected *Y* or delta, or combinations of each.

A *Y*-connected transformer has the advantage of producing secondary voltages for light and power. Its grounded neutral wire allows a balanced load to be maintained. When used for a step-up transformer, fewer turns are needed in the secondary windings, since the line voltage is $\sqrt{3}$ times the phase voltage.

A delta-connected transformer has the advantage of continuous emergency operation. Removal of a burned-out phase results in *V* or open delta connection, which can operate on a reduced load of 57.7 percent.

QUIZ

1. What lines carry the current between the generator plant and the distribution center?
2. What name is given to the wires between the distribution centers and the transformers?
3. What lines carry the current between the transformers and the electrical equipment in the area?
4. Name two different connections for the stator coils of a three-phase generator.
5. When using a four-wire 2300/4160-volt distribution system, what is the voltage between any one phase and the neutral wire?
6. In a step-down transformer, which winding has the most turns, the primary or the secondary?

7. How many moving parts are there in a voltage transformer?
8. Why are the housings of some transformers corrugated?
9. What liquid is used in some transformers to aid in heat transfer?
10. Is it possible to use three single-phase transformers to secure a three-phase secondary from a three-phase primary?
11. Is the primary or the secondary connected delta in a Delta-Y transformer connection?
12. How may two single-phase transformers be wired to give three-phase service?
13. What is the big advantage of the Delta-connected transformer?
14. At what point is the neutral conductor attached in a Y-connected transformer?

CHAPTER 9

POWER-LINE CONSTRUCTION

AT THE BEGINNING

When an advanced base is first set up, doing the impossible is the order of the day. As a CEL, you're going to get your share when you string the overhead distribution system.

No regular wooden poles? Well, don't let that bother you. A tree that's straight enough to use "climbers" on will do the trick. But don't get choosy. If a tree isn't available, try some pilings or two-by-fours. The important thing is—GET THE WIRES UP IN DOUBLE-QUICK TIME.

This isn't a pep talk, but the cold, hard facts. Those linemen in figure 238 aren't stringing wires on a barber pole. Notice how the insulators are tied to the tree.

Figure 238.—Can do.

LATER ON

An overhead distribution system is only as good as the supports which hold it up. If the advance base is placed on a permanent basis, the distribution system will need a facelifting. New routes must be laid out, holes dug, and temporary supports replaced with REGULAR WOODEN POLES.

When the Navy gets a good man, it expects him to stay around awhile. That's why the doctors did all that tapping and listening when you took your physical. They wanted to be sure you met the physical STANDARDS of the Navy. Wooden poles are expected to last a while, too. Naturally, you won't find a medico going around making each pole say "aahh." But you will find that a pole must pass certain tests of strength, soundness, and shape before it can be used as a line support.

HIGH STRENGTH standards are maintained by the use of certain types of trees. WESTERN CEDAR and SOUTHERN PINE make up most of the Navy's stock.

SOUNDNESS standards are met by an inspection of each pole for defects in the wood. Scars, knots, and splits, unless limited in size, will eliminate the pole from service. Fungus growth and insect damage usually indicate a sickly pole that must be discarded.

SHAPE standards refer to the amount of curvature of the pole. If there are excessive crooks or curves, the pole is not used.

Pole Language

If you don't know the butt end of a pole from a hole in the ground, you don't know "pole language". There's no excuse for that, so suppose you look at figure 239.

All poles have some curvature or SWEEP. The one in figure 239 is exaggerated, of course, for explanation purposes. Notice that the inside of the curve is termed the FACE and the outside the BACK. Knowing which is the face and back of a pole is important. You can determine it easily enough by sighting along the length of the pole.

The BUTT END of the pole will always have a greater circumference than the TOP END. It is the butt end, of course, that you set into the ground. A ROOF is formed by making a 45° cut at the top end of the pole. The roof will shed rain and prevent water from collecting on the top end. This decreases the possibility of decay.

Crossarms must be kept in a steady position when bolted to the pole. GAINS, or notches, cut into the side of the pole provide a flat surface for this purpose. Notice that the gain is placed on the face of the pole.

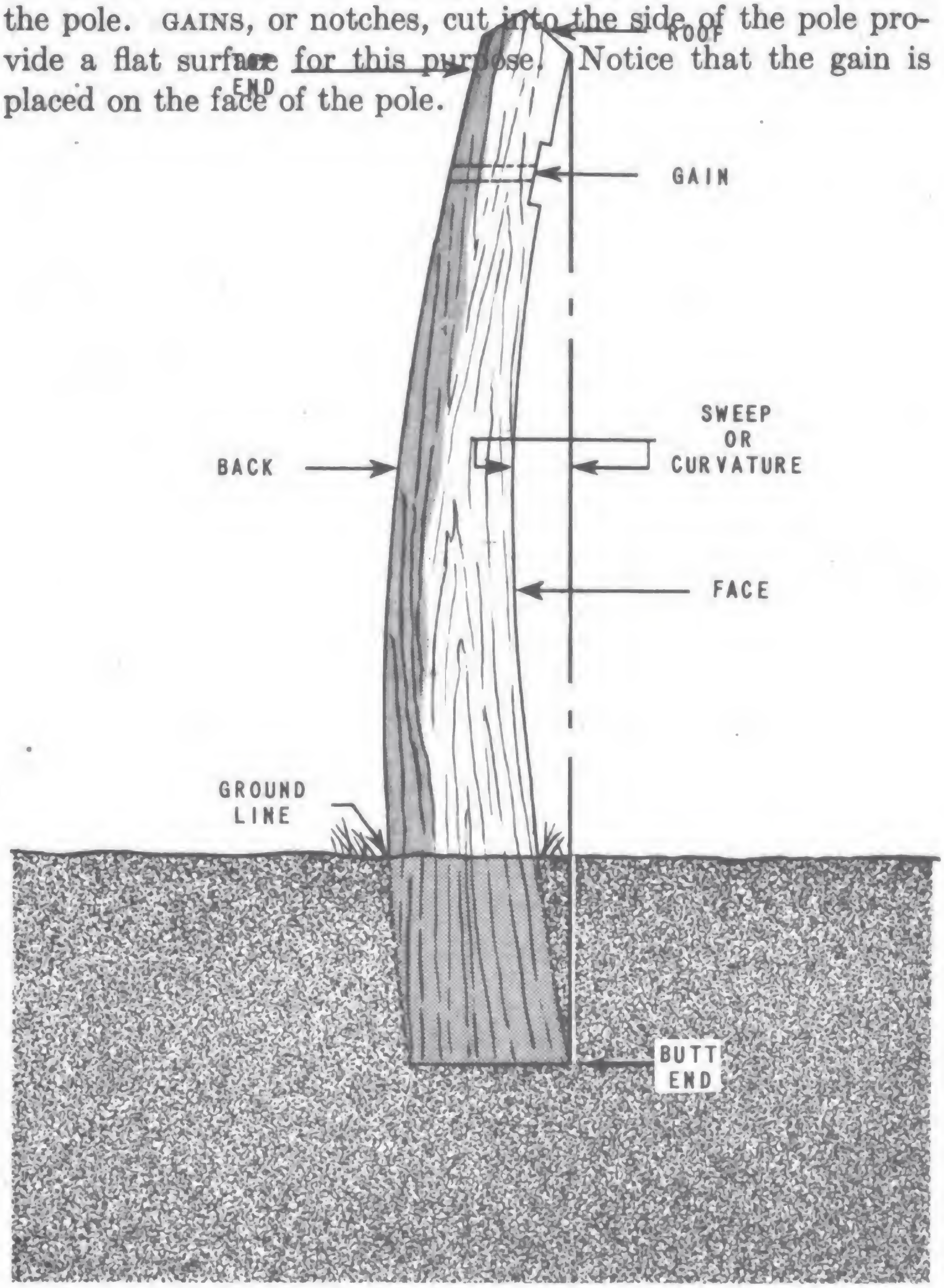


Figure 239.—Pole language.

Pole Protection

The life of a pole can be increased by covering it with CREOSOTE OIL. There are two or three different methods of soaking

the creosote into the wood, but the end result is the same—insects and fungus growth curl up and die when they get a whiff of it.

Some woods have a high natural resistance to decay. Western cedar poles, for example, need only a covering of creosote extending from the butt end to 2 feet above the ground line. This provides protection for the part of the pole set in the ground.

Other woods, like southern pine, will need a full-length treatment. Here's a word of caution—a pole with a full-length treatment requires special care in climbing. Creosote is a toxic compound that will blister the skin. When climbing this type of pole, be sure to use gloves for protection.

MEN AT WORK

Machines have been invented to do just about everything. For example, that EARTH BORER in figure 240 will drill a hole in a matter of minutes. And the POLE DERRICK shown in the same

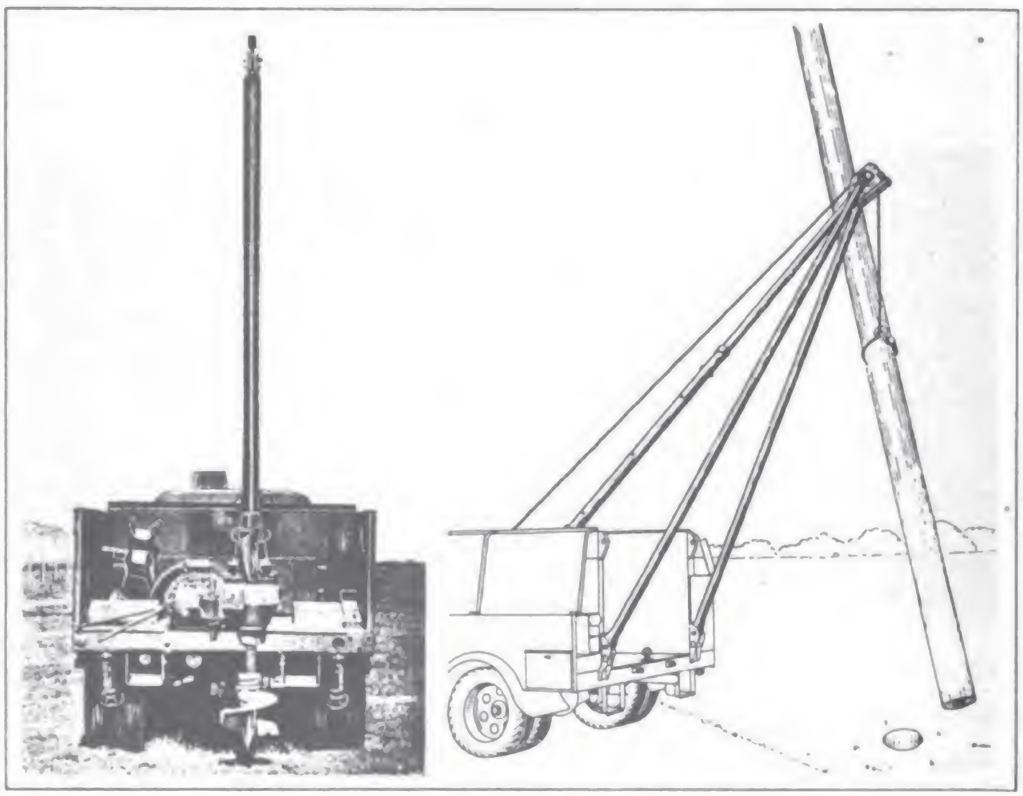


Figure 240.—Earth borer and pole derrick.

figure is no slouch either. It'll pick up a pole and set it in a hole as easy as you handle a matchstick.

This should all sound mighty good to you. After all, you're the man who's supposed to dig the holes and set the poles. But don't start dreaming too soon. In fact, you had better uncoil from that reclining position and start looking for a shovel. Why? Because that power equipment has to be available before you can use it. And nine times out of ten it won't be around just when you need it.

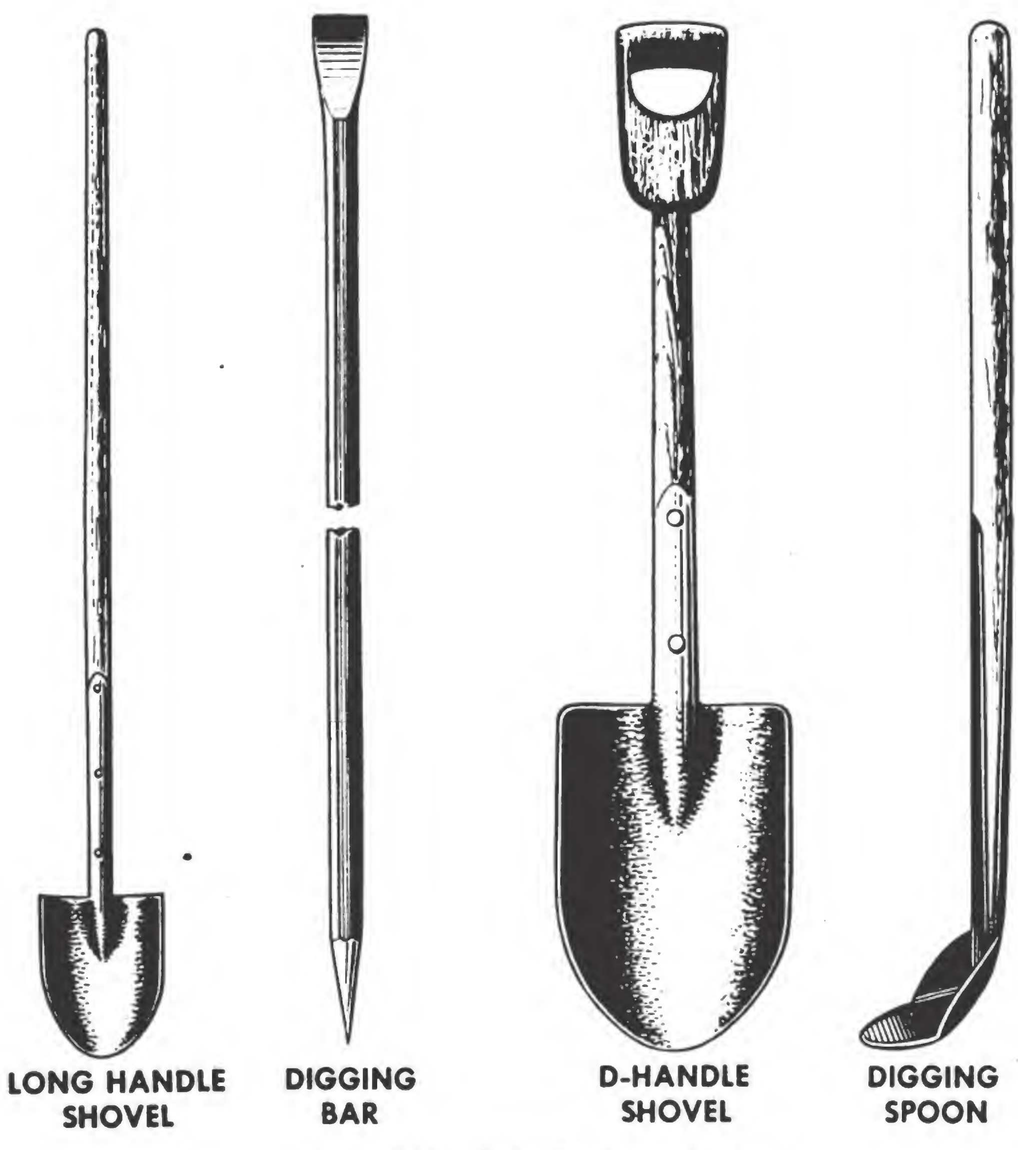


Figure 241.—Pole-digging equipment.

Digging the Hole

Digging a ditch is easy. You can get right down on the bottom and scoop out the dirt from there. Digging a pole hole is a little harder. First of all, you're limited as to the size of hole. It should be only slightly larger than the diameter of the butt end of the pole. That means you have to scoop out all the dirt from the top of the hole. Secondly, you've got to dig down deep—in some cases as much as 9 feet. And the holes must be of uniform diameter from top to bottom. All this calls for special digging tools with long handles, plus the ability to use them properly.

All the pole-digging equipment that you'll use is shown in figure 241. The first few feet of the hole can be handled with the short D-HANDLED SHOVEL. The LONG-HANDLED SHOVEL is then used for the remainder of the hole.

You may find it difficult to remove the dirt with the long-handled shovel. This will be especially true when the soil is dry and won't stick to the blade. The problem is solved by using the DIGGING SPOON. The blade of the digging spoon is set at an angle. A scooping motion is used to lift the loose soil from the hole. Frozen ground, rocky soil, or hard clay might put up a fight. In that case, you'll employ a DIGGING BAR to loosen the soil.

Pole-Raising Equipment

It's a good idea to become familiar with the equipment pictured in figure 242. Each of the tools shown will make the work of erecting poles by hand a little easier for you.

The CARRYING HOOK, or LUG HOOK, is an aid in moving poles. It is built on the ice-tong principle. The two sharply pointed tongs are pivoted at one end so as to fit any size pole. The long carrying handle permits the use of one or two men on each side of the hook. The weight of the pole is evenly distributed by placing a carrying hook at the butt and top end.

The DEADMAN or "mule" is used as a pole support during erection. It consists of a long stick fitted with a spike at one end and an iron fork on the other. The curve of the iron fork fits the arc of the pole. The spiked end digs into the ground and prevents the mule from kicking out.

The WOOD SUPPORT or "jenny" serves the same purpose as the deadman. Its A-frame construction gives it greater support-strength.

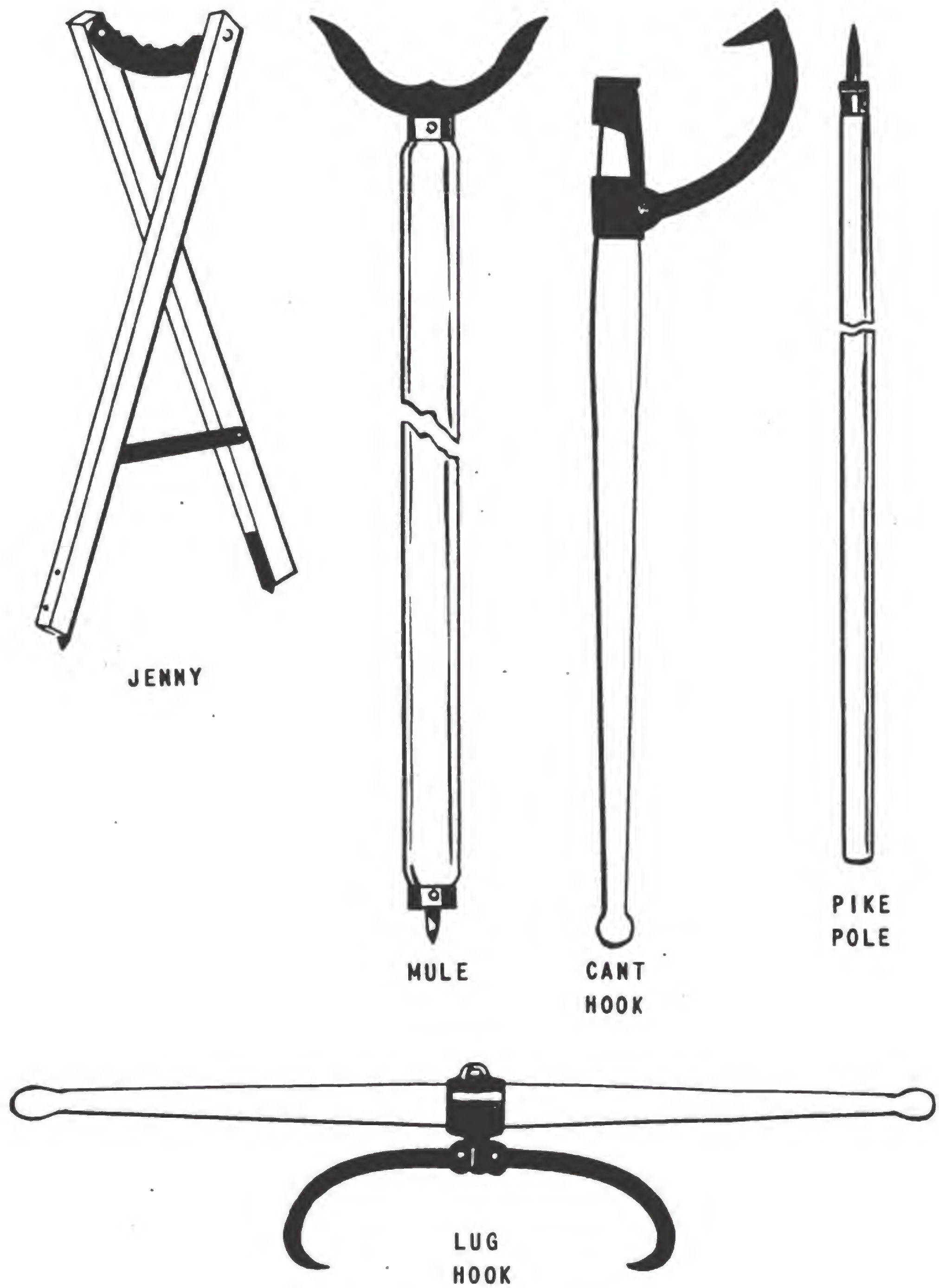


Figure 242.—Pole-raising equipment.

The CANT HOOK comes in handy when the pole must be turned or rolled. Pulling on the handle in a direction away from the hook will cause the hook to bite into the pole. Further turning will rotate the pole. Two cant hooks can be used to maintain the pole in a steady position as shown in figure 243.

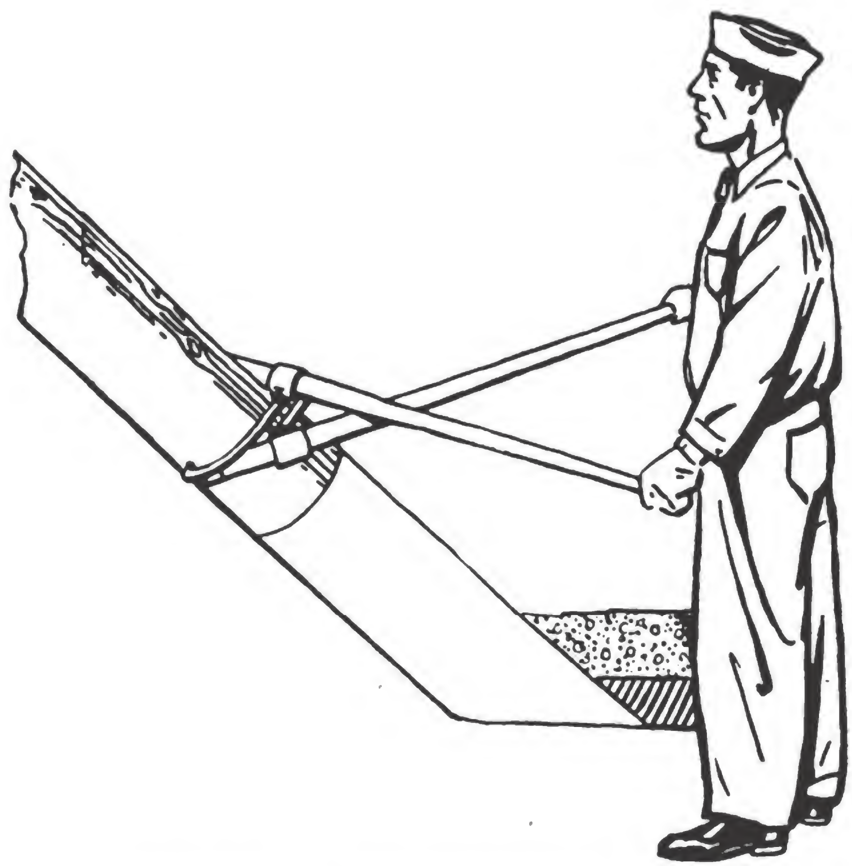


Figure 243.—Steadying the pole with two cant hooks.

PIKE POLES add extra lengths to your arms. They are long wooden poles with a spike at one end. As you up-end the pole, you can continue to exert pressure on the top end by the use of pike poles.

Raising the Pole

As part of a crew that's raising a pole you have more than just yourself to think about. Every man on that crew is depending on you to do your job correctly. It's all a matter of common sense but keep these things in mind:

1. Make sure your footing is secure.
2. Keep your mind on the job at hand.
3. Make changes in position only when ordered to by the man in charge of the crew.

Before you can start raising the pole it must be placed in position near the hole. This is shown in figure 244. The butt end of the pole overhangs the lip of the hole and rests against the BUTTING BOARD. The butting board is a plank that helps to guide the pole and prevent the sides of the hole from caving in. Notice that the pole rests in a sloped trench. The trench aids in easing the butt end of the pole into the hole.

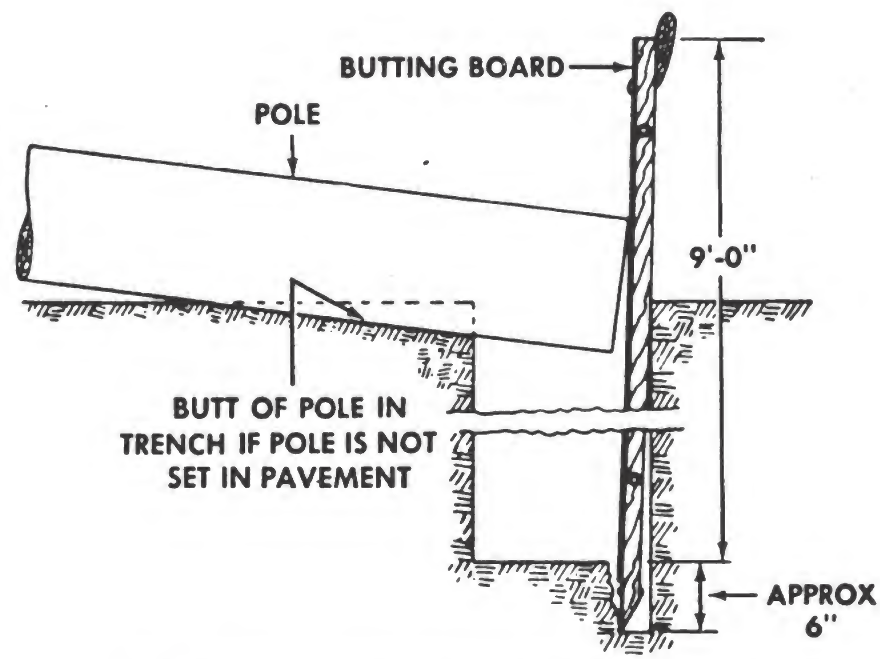


Figure 244.—Proper position of pole for raising.

Now comes the hard work. Your position in the crew will depend on the job you have to do. As a jennyman you will have the responsibility of moving the jenny into position. If your job is to keep the pole steady you will be operating the cant hooks at the butt end. If you're assigned to the PIKER crew, then you will lift the pole.

Figure 245 shows the first step in up-ending the pole. The pikers grasp the pole under the top end and raise it up. The

jennyman eases the jenny snugly under the raised end to take the load.

The second step consists of lifting the pole as far as possible without pole pikes. The pikers are evenly distributed on each side of the pole (figure 245). Each piker pushes upward and toward the man on the opposite side of the pole. The jennyman moves the pole support forward to catch the weight as the pole is raised. The pikers move three or four feet toward the butt end and repeat the process. The jennyman always moves forward to catch the load. This continues until the end of the pole is 12 to 15 feet from the ground.

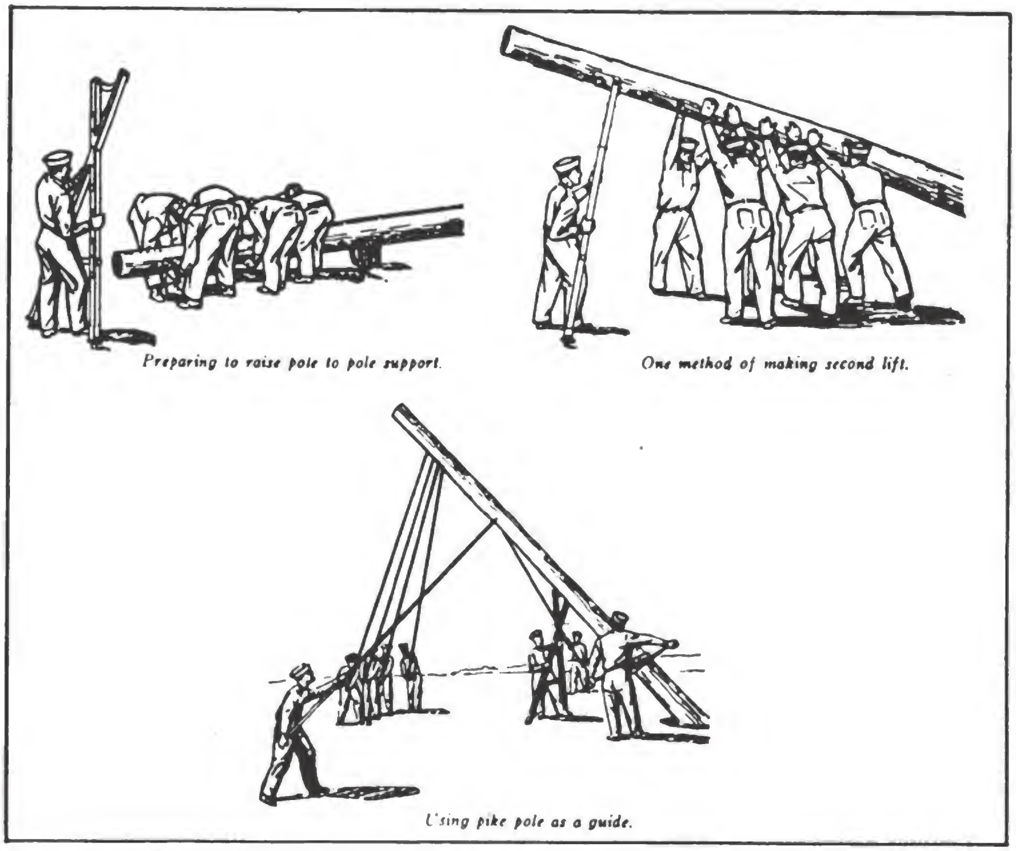


Figure 245.—Raising the pole.

Now the pike poles are brought into play. Each piker jabs his pike, one at a time, into the pole. Figure 245 gives you the whole picture of the final lift. You can see the exact position of the cant hook man, jennyman, and pikers. Notice that

two pikers are set off to each side of the pole. They help to guide the pole.

Pushing up and forward on the pikes raises the pole. The jennyman holds the pole support in readiness to take the load if need be. A point will be reached where a pike man will have his pike too high up the pole to be effective in lifting. This man calls "High pike" and the lifting stops. The piker on the lowest position of the pole pulls his pike out and jabs it in further down the pole. Each of the other pikers follows suit. The piking continues until the pole eases into the hole. The pikers must be sure to keep a firm hold on their pikes when this happens.

Facing the Pole

After the pole has been set in the hole, it must be FACED in the proper direction. That means turning the pole so that the gains or cross-arms, if already installed, will be on the proper side. For example, in straight sections of line, the gains of alternate poles are faced in opposite directions. The result is an increase in the strength of the line.

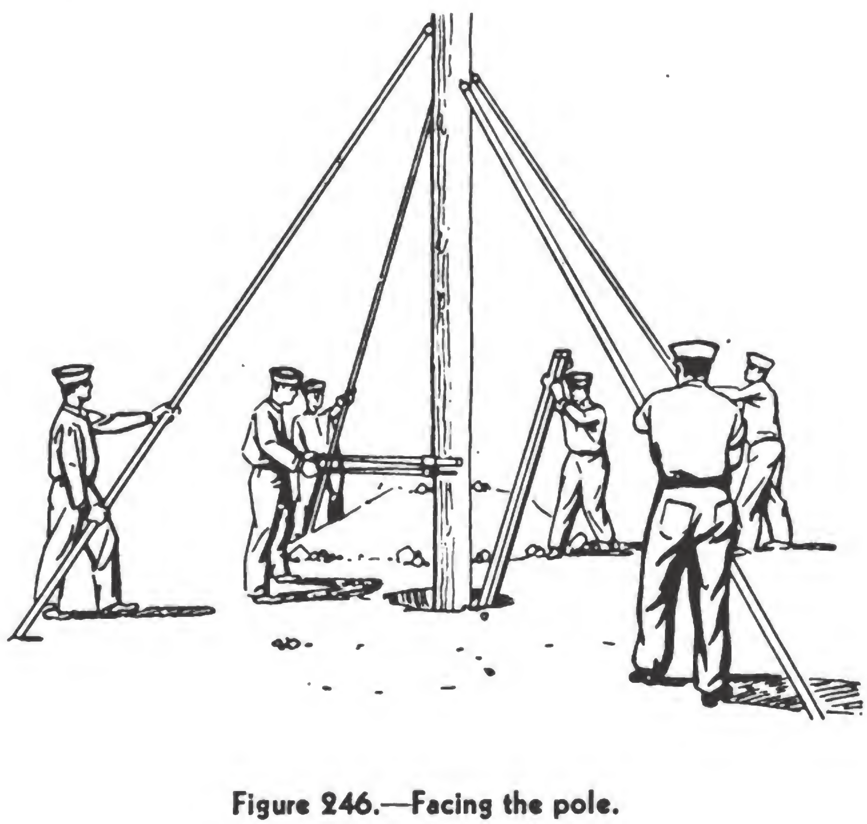


Figure 246.—Facing the pole.

Figure 246 shows how the pole is faced. Cant hooks supply the leverage necessary to turn the pole. Four pike poles are equally spaced around the pole to hold it in an upright position.

Lining In and Straightening Up

After facing has been completed, the pole should be lined up with those already set in the string. To bring the pole in line, it is necessary to shift the position of the butt end in the hole. A heavy bar may be used to force the butt end over.

Shifting the butt end might cause the pole to lean. That is, the butt end and top end will not be in the same perpendicular line with respect to the ground. The pole must then be straightened up by shifting the top end. The four pikers, who are equally spaced around the pole, will push the top end into position as directed by two SIGHTERS. One sighter stands along the line, the other at the side.

Backfilling and Tamping

The pole has been faced, lined in, and straightened up. Now you're ready to provide it with a permanent support. Do this by filling the space between the pole and the sides of the hole. This is called backfilling. As the dirt is shoveled back into the hole, it is packed tightly by continuous tamping. After the hole has been completely filled, the remaining dirt is piled up around the base of the pole.

CLIMBING WOODEN POLES

You've been given the preliminary instructions on climbing. You're all set for your first practice climb. Feel scared? Well, don't be ashamed of it because that's a natural reaction. Of course, being frightened isn't going to keep you from climbing that pole. Why? Because Joe Doaks over there on the next practice pole is going up. And if he can do it, so can you.

Before you know it, you're at the top. With a smooth motion, you slip the safety strap around the pole and hook it. You feel kind of proud of yourself but you don't relax a minute. You know that, as a linesman, you have to THINK SAFETY all the time. Your life may depend on it!

Climbing Equipment

Walking straight up the side of a pole calls for a little help. You get it from the CLIMBER shown in figure 247. The stirrup fits under the instep of your foot, and the leg iron runs along the inside of the calf of your leg. This puts the gaff or sharp-pointed spur in a position to bite into the side of the pole. Two leather

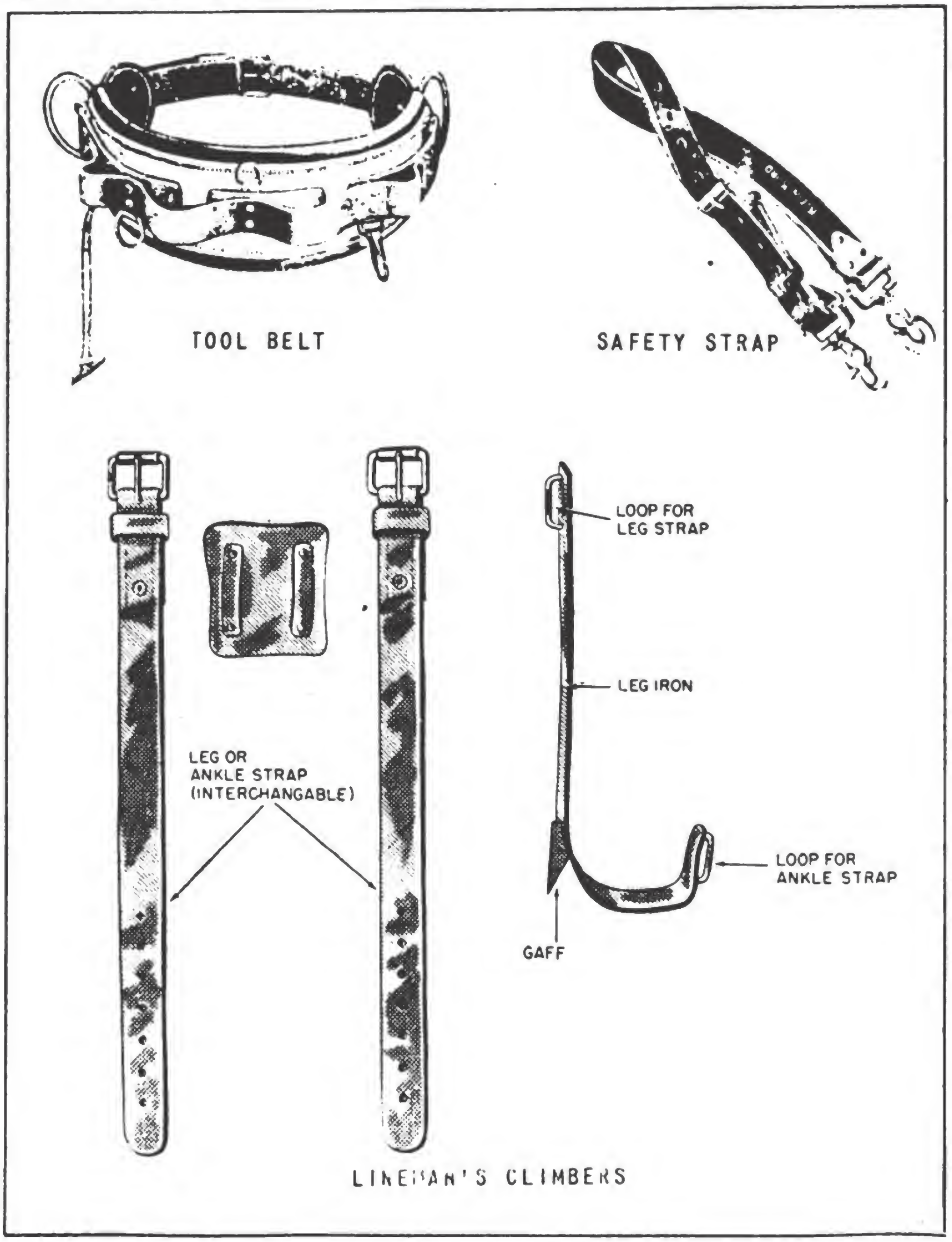


Figure 247.—Pole-climbing equipment.

straps fit through the loop straps, and hold the climber against the calf and ankle. The leather pad keeps the top end of the climber from digging into your leg.

The SAFETY STRAP and BODY BELT (figure 247) are your extra pair of hands. You'll need them when you work on the pole. The body belt is strapped around your waist. It usually contains pockets for small tools. The safety strap is a leather belt with a tongue-type buckle at each end. When climbing, you will have both ends of the safety strap attached to the left Dee ring on the body belt. At the working position you will unsnap one end of the safety strap, loop it around the pole, and hook it onto the right Dee ring on the body belt. By leaning backward against the pull of the safety strap you are able to maintain a steady, safe position.

Climbing-Equipment Care

"Burning" a 40 foot pole isn't a pleasant experience. Besides gathering a lot of splinters on the way down, you'll discover that you're not exactly built for bouncing. The climbers, body belt, and safety belt will help keep you up where you belong—if you take proper care of them.

Before climbing the pole, inspect your climbers. Look for the following defects:

1. Broken or loose straps.
2. Thickness of stirrup worn to one-eighth inch or less.
3. Length of gaff less than 1½ inches as measured along the inner surface.
4. Difference in gaff length of more than one-eighth inch for a pair of climbers.

If you find your climbers in any of the above conditions, turn them in for a new pair. If you find that the gaffs are dull, take the following precautions when sharpening them:

1. Place the climber in a vise.
2. Use a file, never an emery wheel. An emery wheel will heat the metal and cause it to lose its strength (temper).
3. Never sharpen the gaff to a needle point. It will cause the gaff to sink too far into the pole, making climbing difficult.

Always leave a shoulder about one-eighth inch back from the point.

Don't forget that climbers are for use on poles only. Wearing the climbers while working on the ground, or using the gaffs for can openers is taboo.

Your body belt and safety strap need a preclimbing inspection, too. Look for:

1. Loose or broken rivets.
2. Cracks, cuts, nicks, or tears on the leather.
3. Broken buckles.
4. Defective snap hooks on the safety strap.
5. Worn leather.
6. Enlarged holes for the tongue of the buckle.

If you discover any of the above, immediate replacement is necessary.

Taking care of the leather is also part of your maintenance job. Cleaning the leather comes first. Use a damp sponge and a mild soap. Work up a creamy lather. Then wash the soap off and wipe the belt with a dry cloth.

Making the leather soft and pliable is the next step. This is done by lathering the belt with SADDLE SOAP. Work the lather into all parts of the leather equipment. Then place the belt in the shade to dry. After the lather has nearly dried, rub the leather with a soft cloth.

Body belts and safety straps will require oiling about every 6 months. Be sure the leather is clean before applying the oil. Use about 2 teaspoonfuls of NEAT'S-FOOT OIL, and gradually work it into the leather. Pick a shady spot for drying the belt. Allow enough time (24 hours) for the oil to dry slowly. Then use a soft cloth to remove the excess oil.

Going-Up

You'll never learn how to climb a pole unless you actually get out and practice on one. But knowing a few tricks of the trade will save you a lot of wear and tear. First of all, make a preclimb inspection. Examine your climbers, body belt, and safety strap. Make sure they are in good condition. Then

inspect the pole for the best position from which to start the climb. Wherever possible, choose the back, or high side, of the pole.

Now, you're ready to begin the climb. Grasp each side of the pole with your hands. Remember that you're not going to shinny up the pole. Your hands are not used to support any weight. They merely help to keep your balance on the climbers.

Raise your right leg about 8 inches off the ground and sink the gaff into the pole. Don't jab the gaff into the wood. Just let the weight of your leg do the job. Now, swing yourself up off the ground and lock your right leg in a stiff-legged position.

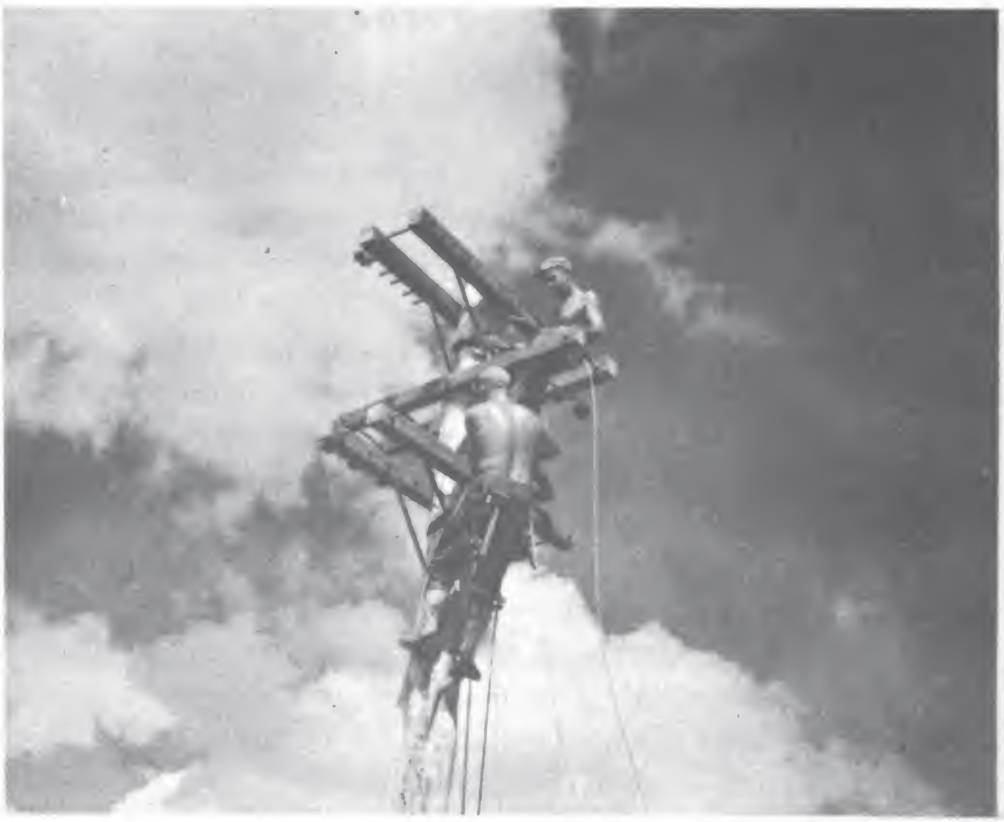


Figure 248.—Working on the pole.

This will enable you to support the entire weight of your body on the right leg. Take the next step by raising the left leg about 12 inches and sinking the gaff into the wood. Swing your weight up onto the left leg and lock the leg in position.

Continue this STEPPING UP and LOCKING until the working position is reached. Don't forget that the top part of your body should be held away from the pole. If you attempt to hug the pole you will throw the gaffs out of the wood.

Working on the Pole

At the working spot the position of your feet should be such that most of your weight is placed on your right foot. The left foot is raised in a bent position slightly above the right foot. Now, here is where your right hand must know what your left hand is doing. Crook your right arm around the pole. Use your left hand to unsnap one end of the safety strap from the left Dee ring on the body belt. Holding the end of the safety strap in your left hand, pass it around the back of the pole. Transfer the end of the safety strap from the left hand to the right hand. At the same time you make the switch, crook the left hand around the pole to hold your position. Then swing the end of the safety strap around with your right hand and snap it onto the right Dee ring. Now, you can release the left hand from the pole and lean back against the pull of the safety strap. Figure 248 shows you the correct working position.

Coming Down

Before you start down the pole you must remove the safety strap. Crook your left arm around the pole. Unhook the safety strap from the right Dee ring with the right hand. Transfer the end of the safety strap to the left hand. Crook your right arm around the pole. Snap the end of the safety strap onto the left Dee ring.

Now, you're ready to descend the pole. Break out the left gaff by swinging the left knee out from the side of the pole. Step down with your left leg to a point about 12 inches below the right leg. Keep the left leg stiff as you step down. The weight of your body will force the left gaff into the pole. Break out the right gaff by swinging the right knee away from the pole. Step down on the right leg, forcing the right gaff into the pole. Continue this stepping-down process until the ground is reached.

SAFETY

Remember that a lineman must always be thinking safety. Keep the following precautions in mind as you work aloft:

1. Never carry tools or other objects in your hand when climbing.
2. Don't trust pins, crossarm braces, or guy wires as supports.
3. If you are working with another man on the same pole, let him climb to his working position before you start up.
4. Don't trust to sound when snapping the safety strap onto the Dee ring. Look down to make sure it is secure.
5. The safety strap should never be placed around that part of the pole which is above the highest crossarm, if the crossarm is near the top of the pole.

CROSSARM CONSTRUCTION

Take a look at a crossarm that's already mounted on a pole and you'll see some interesting details. For example, you'll find the crossarm supporting, but not touching, the distribution wires. The wires are tied in place to GLASS INSULATORS. The glass insulators, in turn, are screwed onto INSULATOR PINS which are set in holes in the top of the crossarm. If the insulator pins have a wooden shank, they are secured to the crossarm with sixpenny nails. Insulator pins with threaded-steel shanks are inserted through the holes in the crossarm and secured with a nut.

The crossarm itself, is mounted in a gain or notch, and attached to the pole by means of a through-bolt. Two flat steel straps serve as braces to keep the crossarm in a rigid position.

If you're looking at the crossarm from the ground you probably are too far away to see the special types of bolts, braces, and washers that are used in its installation. You can get a close-up view of this pole-line hardware by looking at figure 249.

Equipping the Crossarm

Crossarms are usually attached to the pole before it is erected. In some cases, however, you may be called upon to install the crossarm after the pole is in place.

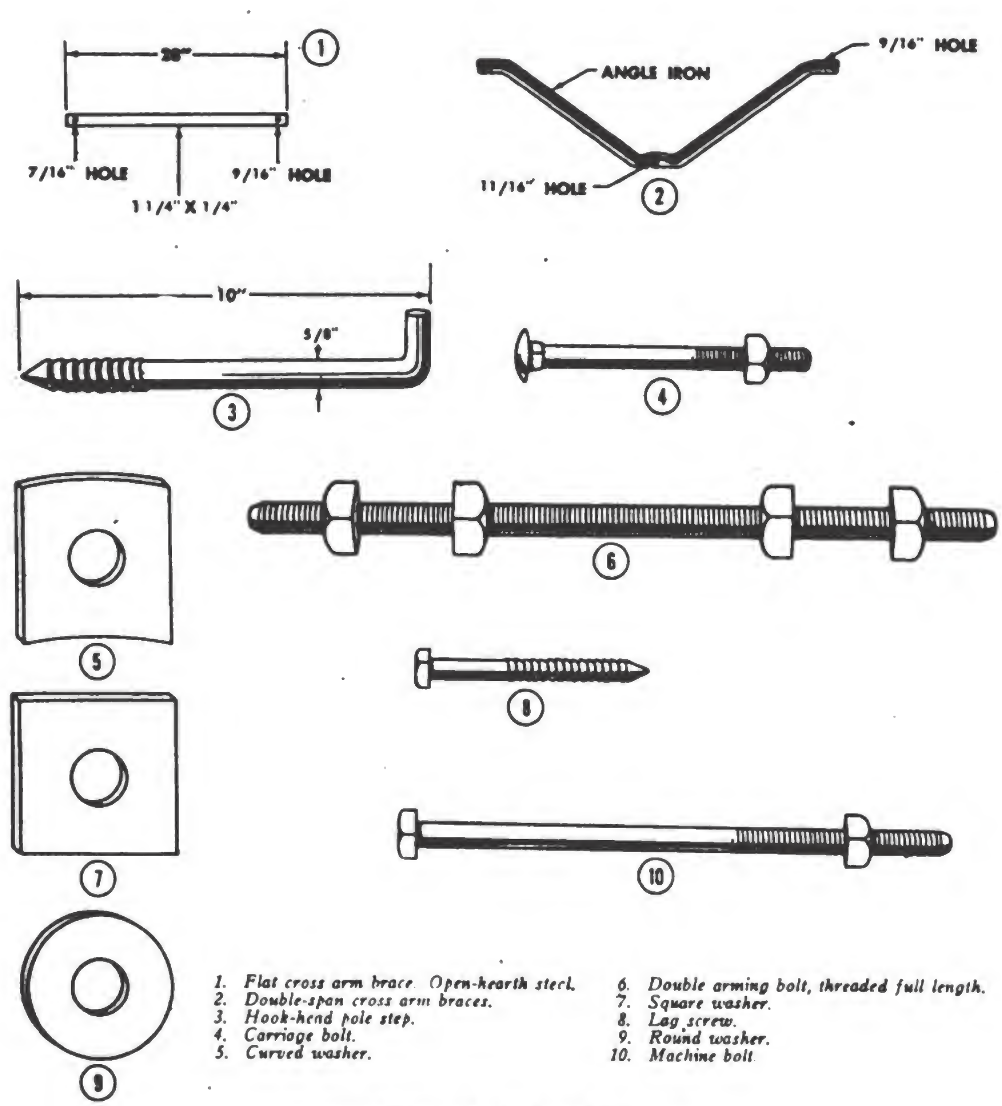


Figure 249.—Pole-line hardware.

The first thing you must do is to equip the crossarm with pins, insulators, and braces. This is done on the ground. The insulators are securely tightened on the pins. The pins are then nailed into the arm with sixpenny nails. Two through-holes on the side of the crossarm are provided for the attachment of the

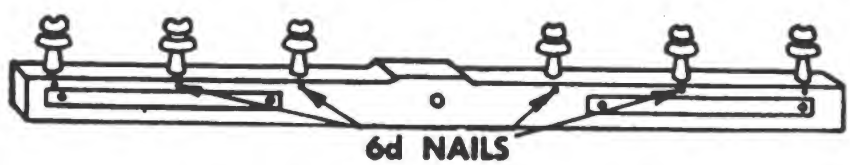


Figure 250.—Equipping the crossarm.

flat braces. A carriage bolt (figure 24) is used to secure each brace to the crossarm. When you are finished, the crossarm will look like the one in figure 250. The braces have been folded up along the side of the crossarm so they won't interfere with its hoisting.

Hoisting the Crossarm

Since you can't carry the crossarm up the pole, you do the next best thing and have it hauled up. A block and tackle is used for this purpose.

The block should be attached to the pole above and to one side of the gain in which the crossarm is to be placed. The ground man attaches the crossarm to the hand line and at your signal begins to hoist it up. This set-up is shown in figure 251.

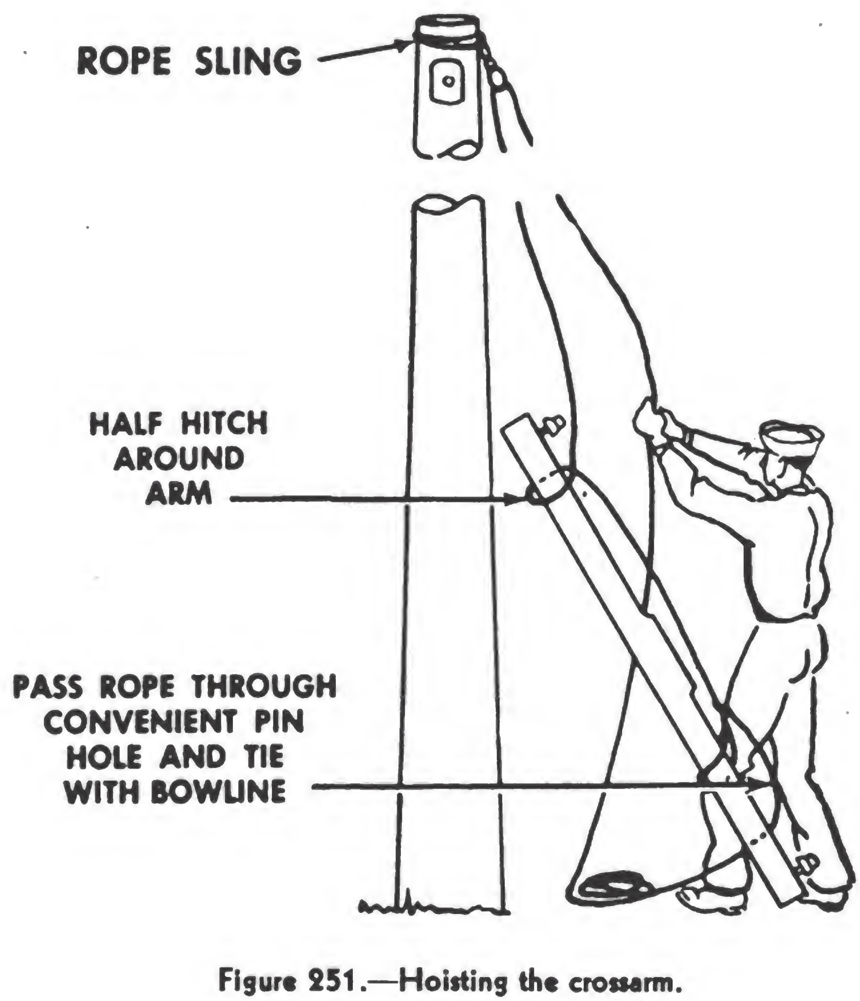


Figure 251.—Hoisting the crossarm.

Installing the Crossarm

Before you give the signal to hoist the crossarm, you've got to make preparations to receive it. That means driving a machine bolt (figure 249) through the gain hole, starting from the back of the pole. Be sure that you place a square washer (figure 249) under the head of the bolt.

Now give the signal to the ground man to start hauling away. As the crossarm approaches, grasp the end and remove the half hitch. Guide the crossarm onto the end of the machine bolt (figure 252). Place a square washer on the bolt, then screw the nut on. Draw the nut up tight with a wrench.

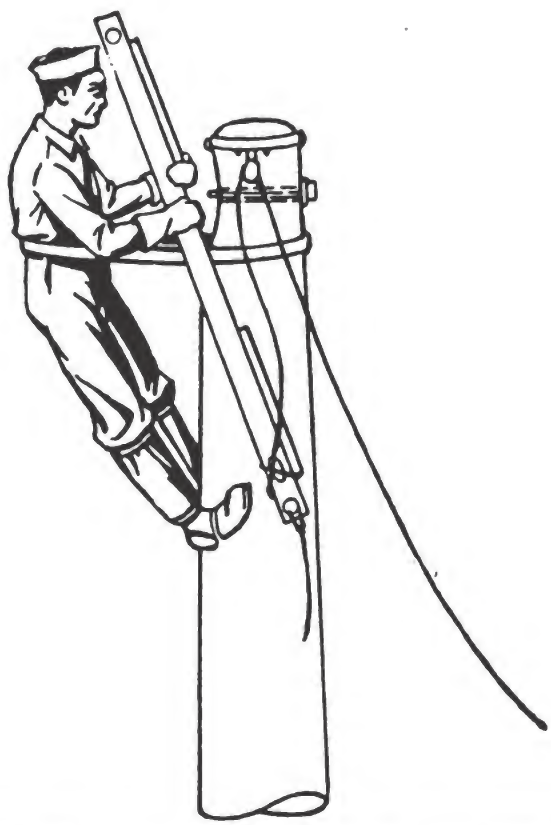


Figure 252.—Guiding the crossarm into position.

Step down to a slightly lower working position to fasten the braces to the pole. Aline the crossarm so that it is at right angles to the pole. Match up the holes on each free end of the two braces. Then drive a lag screw (figure 249) through the holes and into the pole. As soon as the lag-screw threads catch

into the wood, tighten it up the rest of the way with a wrench.

Double crossarms are used whenever extra strength is needed. Figure 248 gives a good picture of double crossarm construction. The same machine bolt is used to hold both crossarms to the pole. The arms are given a solid support at each end by the use of a double arming bolt (figure 249). Only one of the two arms is set in a gain.

INSTALLING SECONDARY RACKS

Secondary racks are used to support secondary distribution wires. A metal frame holds the insulators which carry the secondary wires. The rack is placed on the pole in a vertical position as shown in figure 253. Through-bolts secure the rack to the pole.

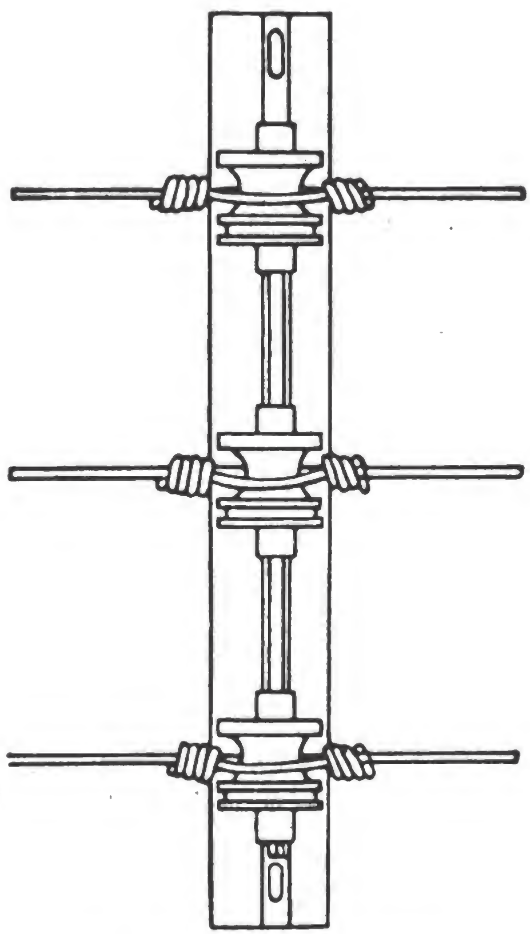


Figure 253.—Secondary rack.

GUYING THE POLE

Whenever a pole, or cross arm, is subject to unequal pulls from the wires it is carrying, a GUY must be installed. The guy, of course, is nothing more than stranded steel wire. One end of the guy is attached to the pole and the other to an anchor in the ground. The guy is always placed so that its pull is opposite to the force that's trying to topple the pole over.

Types of Guys

Guys are classed according to their position with respect to the pole. Figure 254 shows the main types.

Line-terminal poles require a HEAD GUY (view *A*). The guy is placed in line with the conductors which are dead-ended on the pole. The pull of the guy then balances the pull of the conductors.

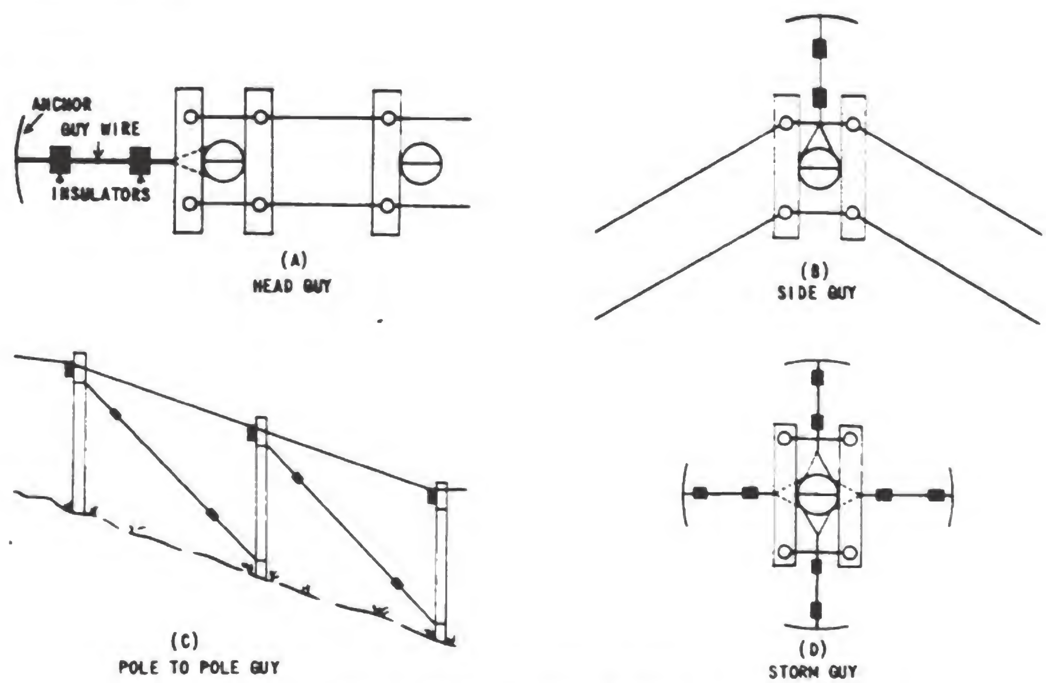


Figure 254.—Types of guys.

When wires change their direction of travel, they place a side strain on the pole (view *B*). A SIDE GUY counteracts this strain.

Poles which carry wires up the sides of hills are subject to unequal loads. The poles may be strengthened by installing POLE TO POLE GUYS as shown in view *C*.

If the distribution system is in a high-wind area it will be necessary to install STORM GUYS. Since the wind may come from any direction, the guys must be placed accordingly. View *D* shows the method used.

Installing the Anchor

The first step in installing a guy is to get the anchor set into the ground. If you're lucky to get hold of a SCREW ANCHOR (figure 255), your job will be easy. No hole is necessary since

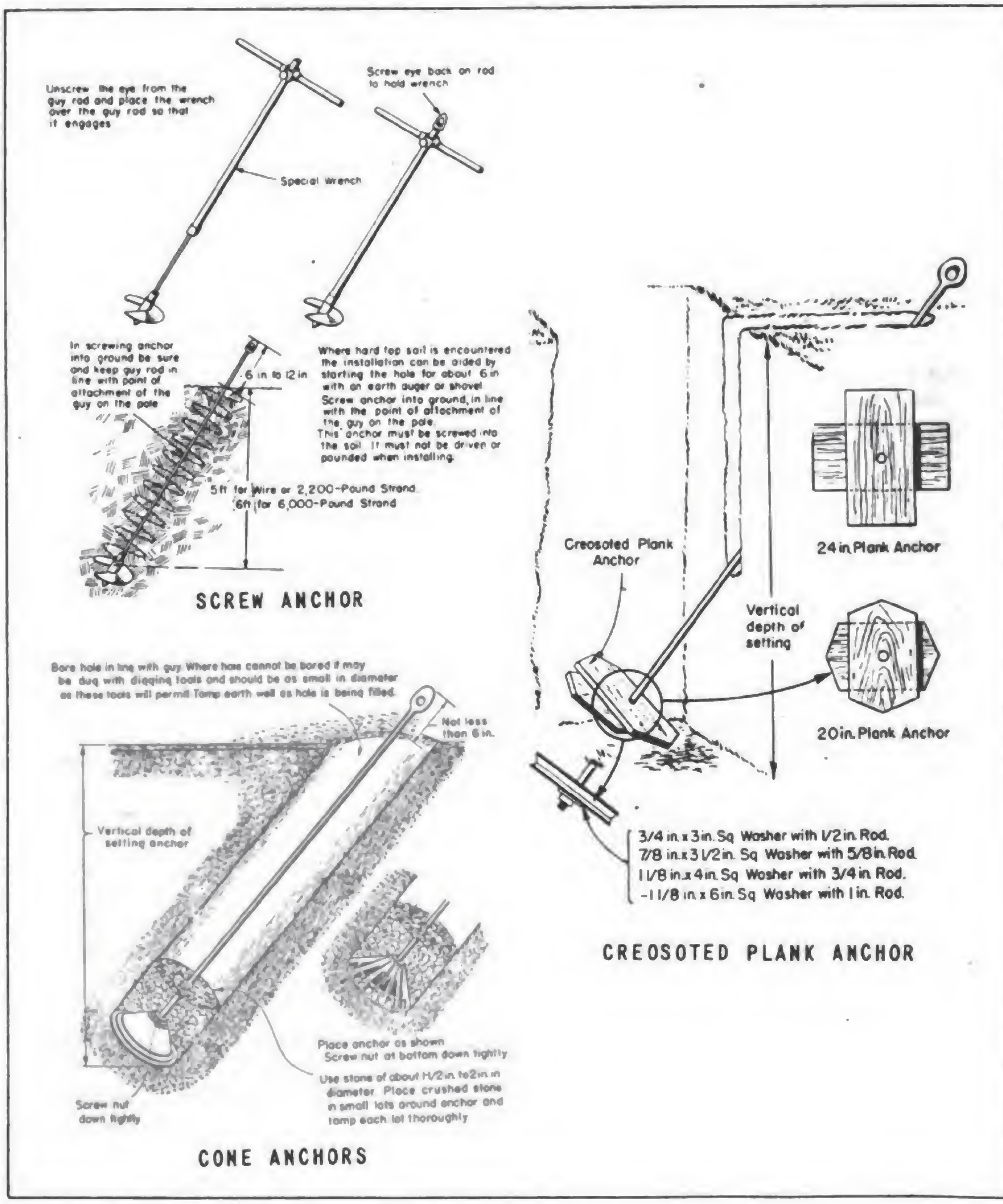


Figure 255.—Installing anchors.

this type of anchor screws into the ground. A special wrench attachment provides the leverage necessary for turning.

A CONE ANCHOR (figure 255) requires a hole. Since the anchor is of small diameter, an earth auger may be used. The hole should be bored at an angle in line with the guy. The anchor, with the anchor rod attached, is placed in the hole, and crushed stone is added. The remainder of the hole is filled with dirt, which is tamped thoroughly.

You may have to improvise an anchor. Logs and planks come in handy for this job. A PLANK ANCHOR is shown in figure 255. A vertical hole is dug for the plank, while a sloped trench holds the anchor rod. Wherever possible, use a creosoted plank or log.

Preparing the Guy Wire

Now that the anchor has been set, your next move is to prepare the guy wire. This is done by cutting the guy wire into proper lengths and inserting porcelain STRAIN INSULATORS.

Strain insulators act as breaks in the guy wire. A live conductor falling on the guy wire will charge the wire only up to the strain insulator. The part of the guy wire which extends from the insulator to the ground will be safe to touch.

The strain insulator is built with two through-holes set at 90° angles to each other. The ends of the guy wire are slipped through the holes, bent back, and clamped tightly to the main part of the guy. This is shown in figure 256.

Figure 256.—Strain insulator installation.

Notice the GUY CLAMP that is used to hold the guy wire. It is made up of two metal bars. Each bar has two parallel grooves on its inner surface. The tail of the guy wire is laid in one groove and the main part of the guy wire in the other groove.

Tightening the nuts brings the two bars of the guy clamp together and provides a secure grip on the tail and guy.

It will be necessary to serve the end of the tail to the main guy wire. This is also shown in figure 256.

Installing the Guy Wire

Now you are ready to place the guy wire between the pole and the ground. One end of the guy is attached to the pole. It may either be wrapped around the pole or threaded through an eyebolt. Both methods are shown in figure 257.

If you use the wrap-around method you will have to install STRAIN PLATES on the poles. The strain plates are curved steel plates which prevent the guy wire from cutting into the pole. The plates are nailed to the pole. GUY HOOKS are used to keep the guy wire from changing its position. A through-bolt clamps the guy hooks to each side of the pole.

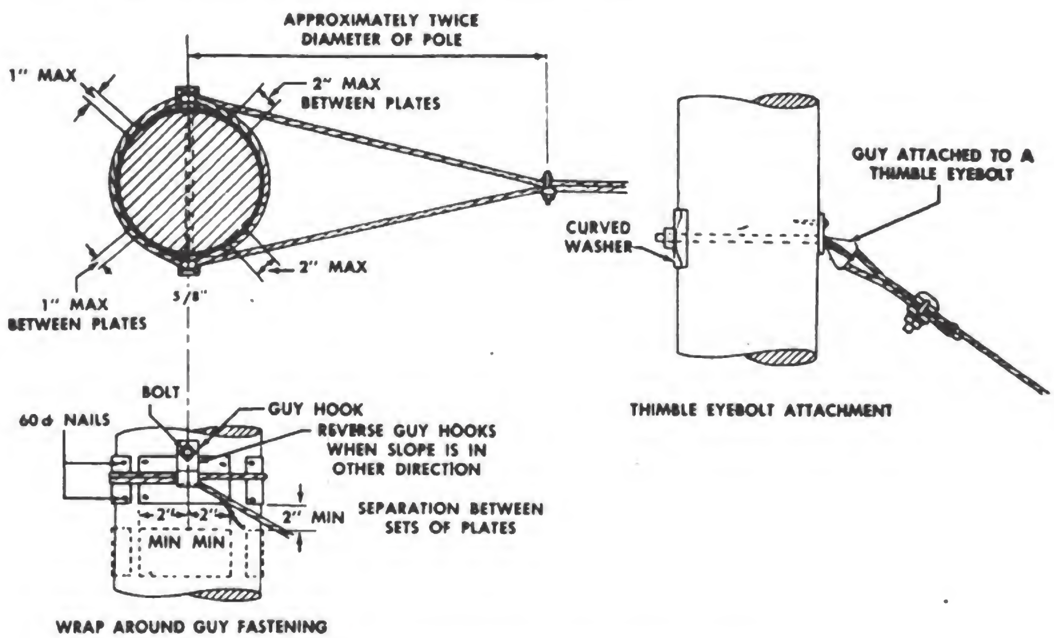


Figure 257.—Attaching guy wire to pole.

In the eyebolt method it will be necessary first, to bore a hole through the pole. The eyebolt is then driven through the hole and securely fastened to the pole. The end of the guy wire is threaded through the eye of the bolt, bent back, and fastened to the main guy with a guy clamp.

The last step in installing the guy consists of attaching it to the anchoring rod and pulling it taut. The free end of the guy is threaded through the eye of the anchor rod. A strand puller or "come-along" is clamped on the free end. Another strand puller is placed on the main guy wire. A block and tackle arrangement connects the two strand pullers together.

The strand puller is a wire-gripper device used in tensioning wires or cables. Its jaws clamp on to the wire and tighten with the pull. The block and tackle arrangement is used to increase the strength of your pull.

PULLING UP STRAND GUY AT GUY ROD

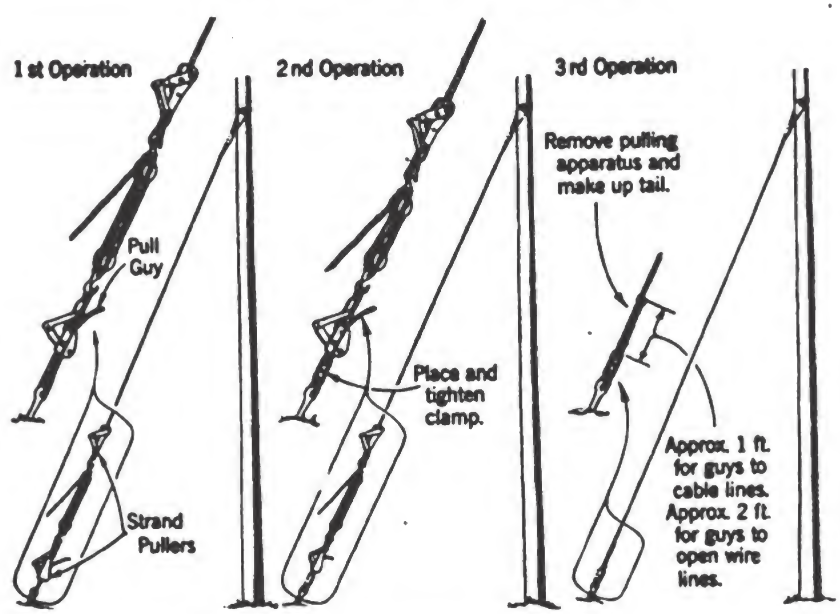


Figure 258.—Tensioning the guy.

Figure 258 shows exactly how to tension the guy wire. As you pull the running end of the rope, the two strand pullers will be drawn together. Since the strand pullers are clamped to the guy, the effect will be a tightening of the guy wire: Continue this operation until the top of the pole is pulled slightly out of line. Then, while the guy is kept under tension, clamp the free end to the main guy. After the guy clamp has been tightened, remove the strand pullers and the block and tackle.

SUMMARY

Wooden poles used as line supports must meet high standards of strength, soundness, and shape.

The length of the pole hole depends on the length of the pole. The diameter of the hole is made slightly larger than the diameter of the butt end of the pole, and must be uniform from top to bottom.

Poles may be set in the ground by hand, by line-truck derrick, or A-frame.

The steps in erecting a pole are: raising the pole, facing the pole, lining in and straightening up, and backfilling and tamping.

Maintenance of climbers includes cleaning and dressing of leather straps and sharpening of gaffs. Body belt and safety straps must also be kept cleaned and properly oiled.

When climbing a pole always remember to keep your knees away from the sides of the pole to avoid throwing out your gaffs.

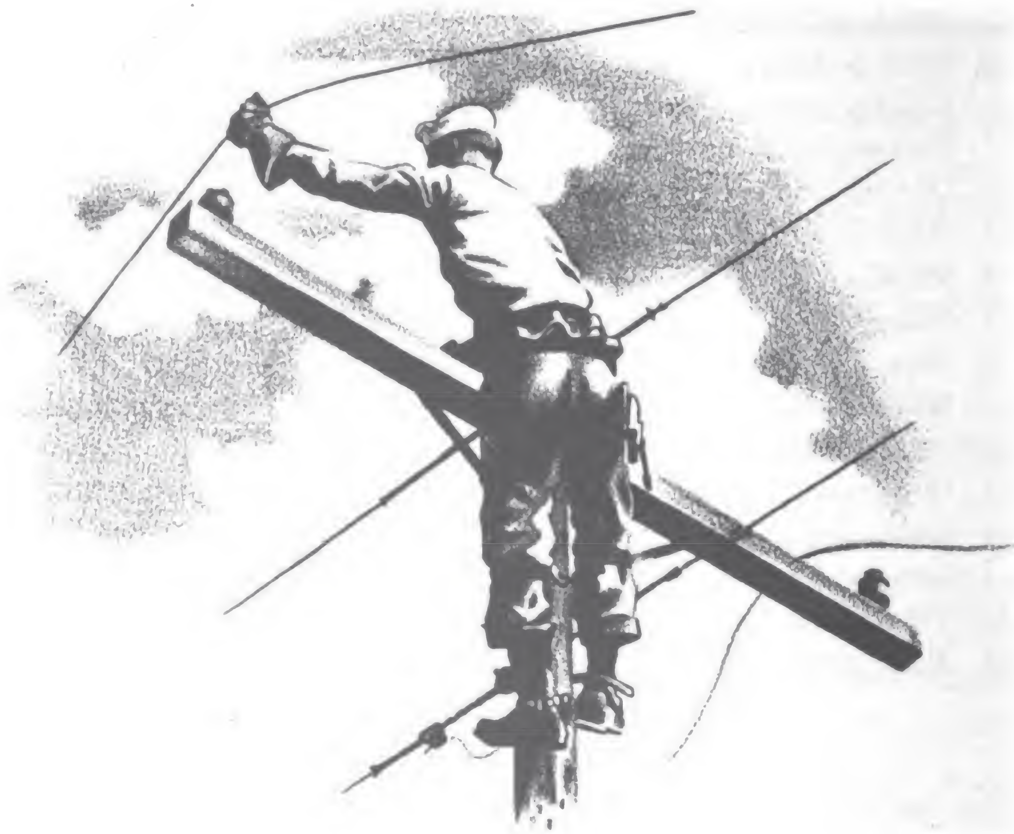
Crossarms are usually equipped with pins, pin insulators, and braces before being hoisted up the pole.

Poles are guyed wherever they are exposed to an unequal strain from the wires or weather.

Guying a pole consists of installing strain insulators, attaching the guy to the pole, attaching the guy to the ground anchor, and pulling to tension.

QUIZ

1. Which end of the pole is placed in the ground?
2. What is the term used for the angle cut made at the top of the pole?
3. Notches are cut into the side of the pole to provide a flat surface for the installation of crossarms. What are they called?
4. On which side of the pole is the notch cut?
5. What preservative is used to prevent decay of the pole?
6. What is the disadvantage of using this preservative?
7. Name two tools used to support the pole during erection.
8. What does the piker crew do?
9. What tools are used to turn the pole after it has been placed in the hole?
10. What are the Dee rings?
11. What type of soap and oil is used on your leather articles?
12. When installing a crossarm after the pole has been raised, how is the crossarm brought to the top of the pole?
13. What is the wire called which helps support the pole?
14. Name three types of anchors.



CHAPTER 10

STRINGING THE POWER LINE

FINISHING UP

The last hole has been dug, the last pole erected, and the last crossarm properly attached. About all you can think of right now is hitting the sack. And it's a good idea. Because tomorrow you'll be out stringing the lines—so you're going to need all the rest you can get.

Stringing a few wires over crossarms might seem like an easy job. And it would be if you only had to handle a few feet of wire at a time. Actually, however, you'll be working with long spans of continuous wire. Try lifting a half mile of solid copper conductor and you get the idea quick.

Teamwork, the proper tools, and a step-by-step process help to lighten the load. Here's what it boils down to:

1. Reeling out the wires.
2. Raising the wires to the crossarms.
3. Tensioning the wires.
4. Tying the wires in.

REELING OUT THE WIRES

Stringing a section of line begins with the laying out of the wires. Reels are used to prevent kinks and mechanical strain.

The size of the reels will depend on the ground conditions. If you're working on smooth ground, the reels may be mounted on a truck. As the truck travels down the section of line, the wire is paid out on the ground. Working on rough ground calls for the use of a portable reel which can be handled by four men.

The length of the section of line might be longer than the length of wire on the reel. When the end of the wire is reached, the empty reel is replaced with a full one, and the wires spliced together. You can use the familiar Western Union splice (chapter 2) if you are working with annealed copper conductors. Since the conductors are already annealed, the use of solder will not weaken them.

Splicing hard-drawn conductors involves the use of solderless connectors. One such type is the SPLICING SLEEVE. It is simply a length of double tubing. You begin the splice by cleaning the ends of the wires which are to be joined together. Then slip each wire through one of the tubes from opposite ends (figure 259). The ends of the wires should extend out about 2 inches from the ends of the tube. Bend the ends of the wire back with a pair of pliers to prevent their slipping out of the sleeve. A sleeve twister or sleeve clamp is then placed over each end of the splicing sleeve (figure 259). Now grasp the sleeve clamps and rotate them in opposite directions. About 3½ turns for each will do the trick. You end up with the conductors and splicing sleeve twisted together in a strong bond (figure 259). The ends of the wires should be cut off.

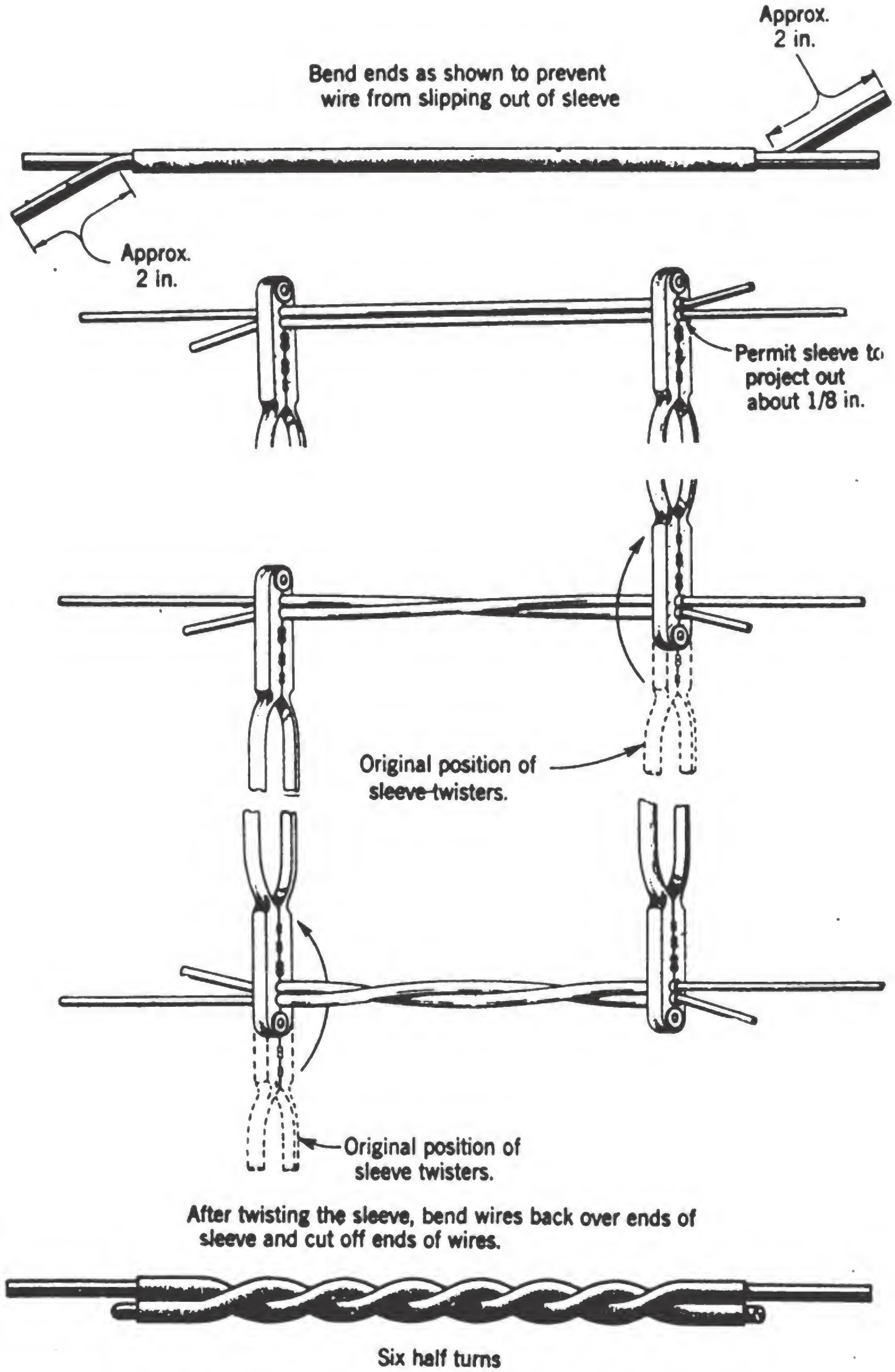


Figure 259.—Making a twisted-sleeve splice.

RAISING THE WIRE

Paying out of the conductor is halted as each pole is reached. At this point the wire is raised and placed on the crossarm. The wire is usually pulled up with a hand line. The reel is then pulled forward to the next pole and the raising process is repeated. Be sure that the wire is placed over the crossarm on the pole side of the insulator pin. This will prevent the conductor from slipping off the end of the crossarm during tensioning operations.

FACTS ABOUT SAG

With the wires placed over the crossarms of the section of line, you are ready to pull them up to the proper tension. Take a look at a completed line and you will notice that each span of wire between poles has a dip or SAG. You might be wondering why the wires weren't pulled taut. After all, the less the length of span, the less will be the weight of wire between any two poles. The answer, of course, is that a tightly stretched wire will break if any additional strain is placed on it. This additional strain might be caused by strong winds, a coating of ice, or contraction of the metal in the conductor.

Too much sag is also undesirable. High temperatures will cause the metal in the conductor to expand. This will tend to lengthen the conductor and thus increase its sag. If it dips too close to the ground, personnel may be endangered.

The amount of sag to which the conductors are tensioned depends on the lengths of the spans, what the temperature is at the time the wire is being strung, and the weather conditions to be expected. You won't have to worry about figuring out the sag. Your job will consist of pulling the wire to the specified dip.

Measuring the Sag

Now, just how do you know when the correct amount of sag has been obtained? Well, there are three methods. The OSCILLATION method uses the principle of vibration of a wire under tension. If you've ever plucked on a tightly drawn banjo string you have noticed how it will continue to vibrate for a short

period. The number of times the middle of the string travels between its highest and lowest point per minute (oscillates) depends on how tight the string is.

The same idea is applied to the conductors being pulled to the proper sag. A middle span is selected in the section of line. The conductor is made to vibrate by striking it from the top of the pole, or pulling down and releasing a piece of rope attached to the middle of the span. A stop watch is used to count the number of complete trips the vibrating wire makes in 15 seconds. A chart is used to convert these readings directly to proper sag. If the number of oscillations is not the same as

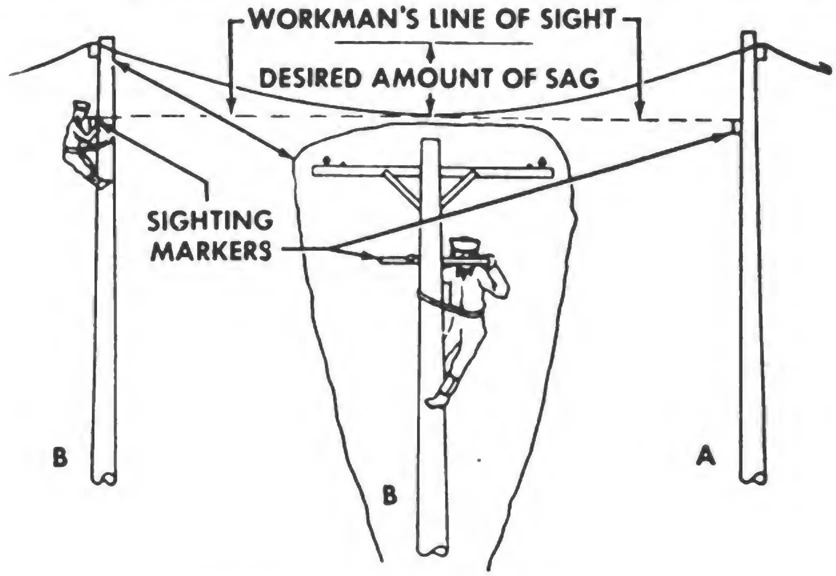


Figure 260.—Sighting the sag.

that required for the specified sag, it will be necessary to increase or decrease the tension in the wire.

Using a DYNAMOMETER is another way to determine the tension in a conductor. A dynamometer is an instrument that records pulling force. It is inserted between the wire being pulled and the pulling source. The tension placed on the wire is read directly from the dial of the dynamometer.

Sag is the distance measured from the lowest point of dip of the conductor to an imaginary straight line between the two points of support. So you can see that SIGHTING the amount of sag directly can be used as the third method. Where the length

of line is short, an average length span somewhere in the middle of the section, can be used for measurement. A sighting marker (strip of wood) is nailed to each of the two poles. The distance from the wire support to the marker is the specified sag. If you are sighting the sag, you will climb the pole and take the position shown in figure 260. You can then signal the pulling crew to tension or slacken the wire until the lowest point of its dip is in line with your marker sight.

TENSIONING THE WIRE

You know how to measure sag or dip. Now you're ready to learn how the wire is pulled to that sag. To help you along, here is the picture of what has been accomplished so far. The wires have been reeled out and raised up and over each crossarm. If the feeder is a three-wire system, there will be three wires loosely strung down the length of the line. If the feeder is a four-wire system, there will be four wires looped over the crossarms.

Each wire will, in most cases, be tensioned separately. The first problem is how to grasp the wire. This is solved by the use of a wire gripper or "come along." The jaws of the wire gripper clamp down over the wire and tighten as you pull. The next problem is where to obtain the necessary pulling power. A block and tackle or motor-driven winch is the answer. If the line is short, the block and tackle can be attached to the top of the pole and the wire tensioned from there. If the line is long, however, the block and tackle can be pulled much easier from the ground. A tree stub or pole will serve as a temporary anchor for the block and tackle.

After the wire has been drawn to the proper tension, the block and tackle is secured. This will prevent the wire from slackening off. The pulling block is released only after the wire has been dead-ended or spliced to the next section of line.

DEAD ENDS

A wire makes a dead end on a pole when it comes up to the pole and stops. Dead ends are found at terminal poles, sharp corners, or where switches are placed in the line.

Small conductors may be dead-ended on pin insulators mounted in double crossarms. A top and side view of this method is shown in figure 261. The end of each wire is brought

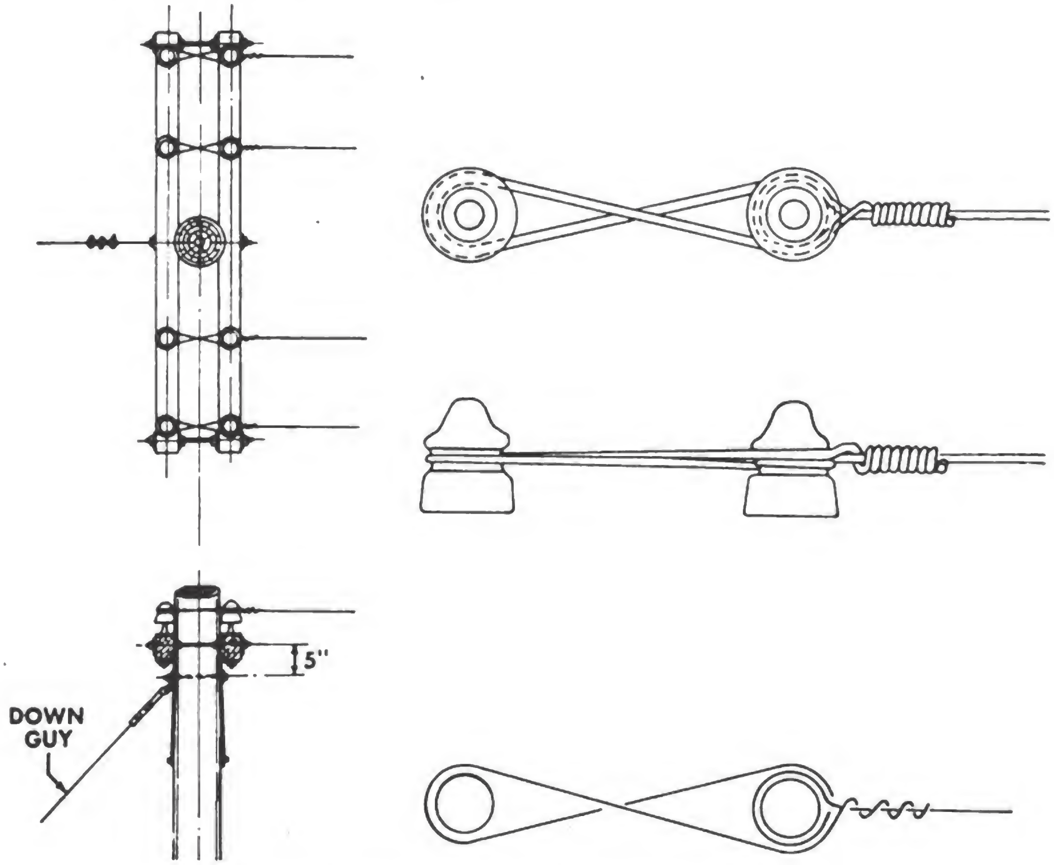


Figure 261.—Pin insulator dead end.

around the side grooves of the pin insulator in a figure-eight design. The tail is wrapped around the main body of the wire. Notice that the pole is a terminal pole. A down guy is used to

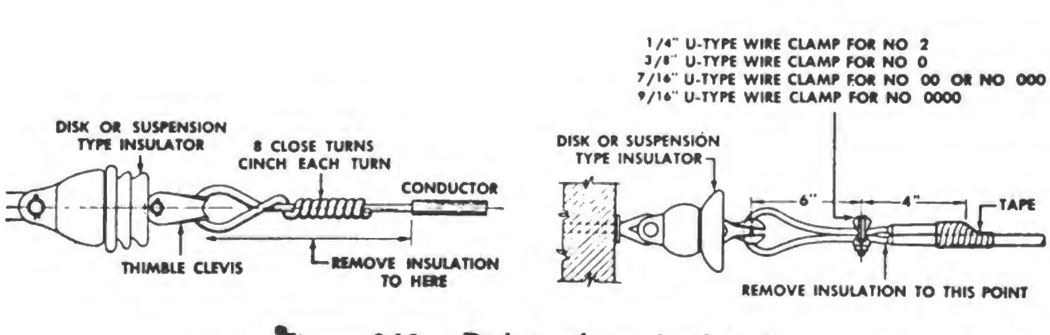


Figure 262.—Disk insulator dead end.

balance the strain placed on the pole by the four dead-ended wires.

Where larger conductors must be dead-ended, stronger insulators are used. One type is the disk or suspension insulator pictured in figure 262. The insulator is attached to a through-bolt in the crossarm. Before the conductor is dead-ended, its insulation must be removed. Bare about 14 inches of conductor but leave approximately 3 inches of insulation on the end of the wire. Thread the end of the wire through the clevis of the insulator, bend back and secure with a U-type clamp. The tail of the wire is attached to the main wire with friction tape.

TYING THE WIRES

After the wires have been tensioned and dead-ended they must be tied to the insulators.

TIE WIRES are used to hold the conductors in place on the insulators. The tie wires average about 3 feet in length. In general the tie wire should be the same size and have the same insulation as the conductor being secured. One important thing to remember is that the tie wires must be of annealed metal. The annealed metal is soft and can be wrapped snugly around conductor and insulator.

The insulators will be either the side-groove or top-groove type. Both are shown in figure 263. The method of making the tie for each type is also pictured.

Here is how you go about making the SIDE-GROOVE TIE. Place the middle of the tie wire on one side of the insulator. Place the line conductor in the groove on the opposite side. Grasp both ends of the tie wire, bring each around the insulator, and loop them under and over the conductor for 1½ turns. Take the end of the tie wire on the left, bring it over the conductor to the right in a long loop and serve it on the conductor for about 2½ closely wrapped turns. Take the end of the tie wire on the right, make a long loop to the left around the back side of the insulator and serve it for 2½ turns on the conductor.

Now for the TOP-GROOVE TIE. Place the conductor in the top groove of the insulator. Place the middle of the tie wire in

the side groove of the insulator. Grasp both ends of the tie wire, bring each around the insulator, and under and over the conductor for two turns. Take the left end of the tie wire and loop it to the right around the side of the insulator and serve it for two turns on the conductor. Bring the right end of the tie wire around the same side of the insulator in a long loop to the left and serve it on the conductor with two tightly wrapped turns.

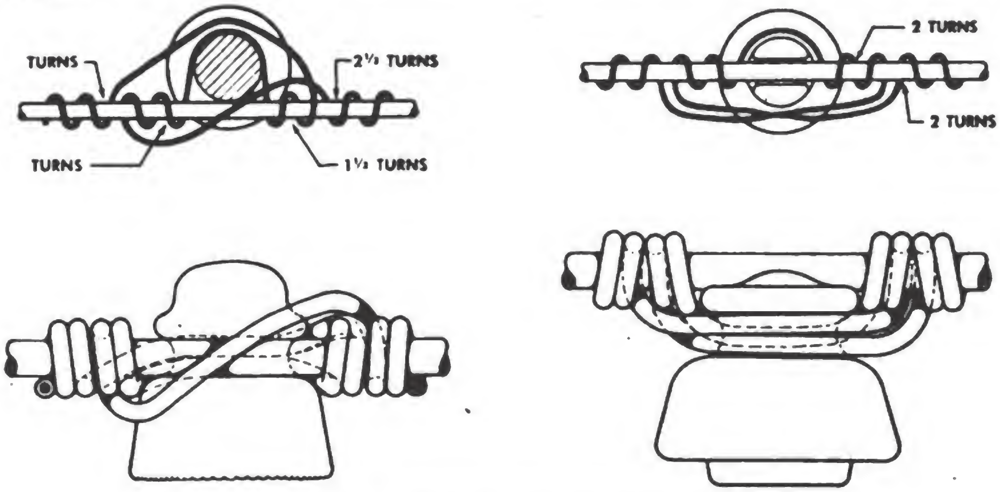


Figure 263.—Side-groove and top-groove ties.

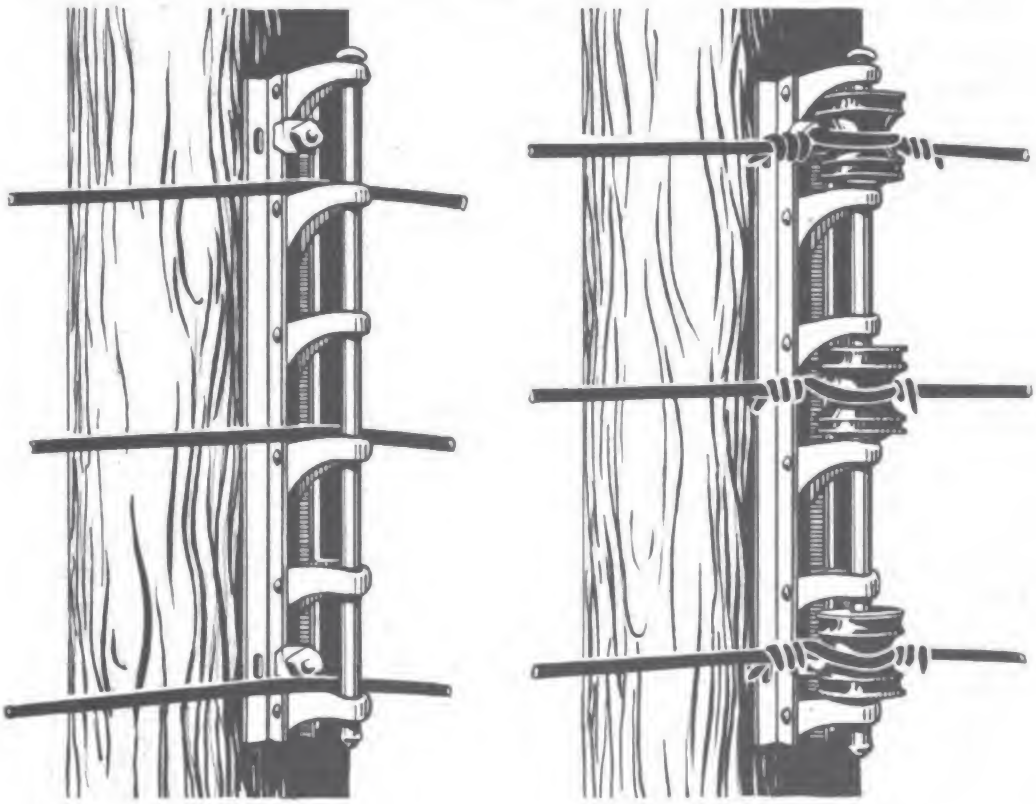
STRINGING SECONDARY MAINS

The wires which carry the secondary voltages are usually strung in a vertical position on secondary racks. The steps in stringing wires on secondary racks are the same as those used for horizontal crossarms.

The construction feature of the vertical rack makes it easy to string the wires. A long vertical bolt holds the spool insulators in place. The insulators may be removed by pulling the bolt up out of the frame. A cotter pin at the end of the bolt normally prevents it from slipping out.

Before the wires are reeled out, the insulators are removed from the racks on each pole. The bolt is replaced. You then begin to play out the secondary conductors along the section of line. As you reach each pole, the conductors are threaded through the secondary racks. The result is shown in view *A* of figure 264.

After the complete section has been strung in this manner, the wires are tensioned to the proper sag. The insulators are then replaced in the secondary racks. The conductors are



(a) (b)

Figure 264.—Stringing secondary mains.

secured to each insulator with a side-groove tie. View *B* of figure 264 shows the completed job.

TRANSFORMER-INSTALLATION FACTS

The distribution transformer steps down the voltage from the primary mains to the secondary mains. Your job will be to: hoist the transformer up and attach it to the pole; connect jumper wires from the primary mains, through fuses, to the primary connections on the transformer; install transformer protection on the primary side in the form of lightning arresters; and connect jumper wires from the secondary connections of the transformer to the secondary mains.

RAISING THE TRANSFORMER

The transformer, of course, is heavy. So you will have to use a block and tackle arrangement to hoist it up the pole. One set of blocks is attached to a support at the top of the pole, the other is attached to the transformer. The pulling line is run through a snatch block at the bottom of the pole. Pulling power is obtained from the line truck.

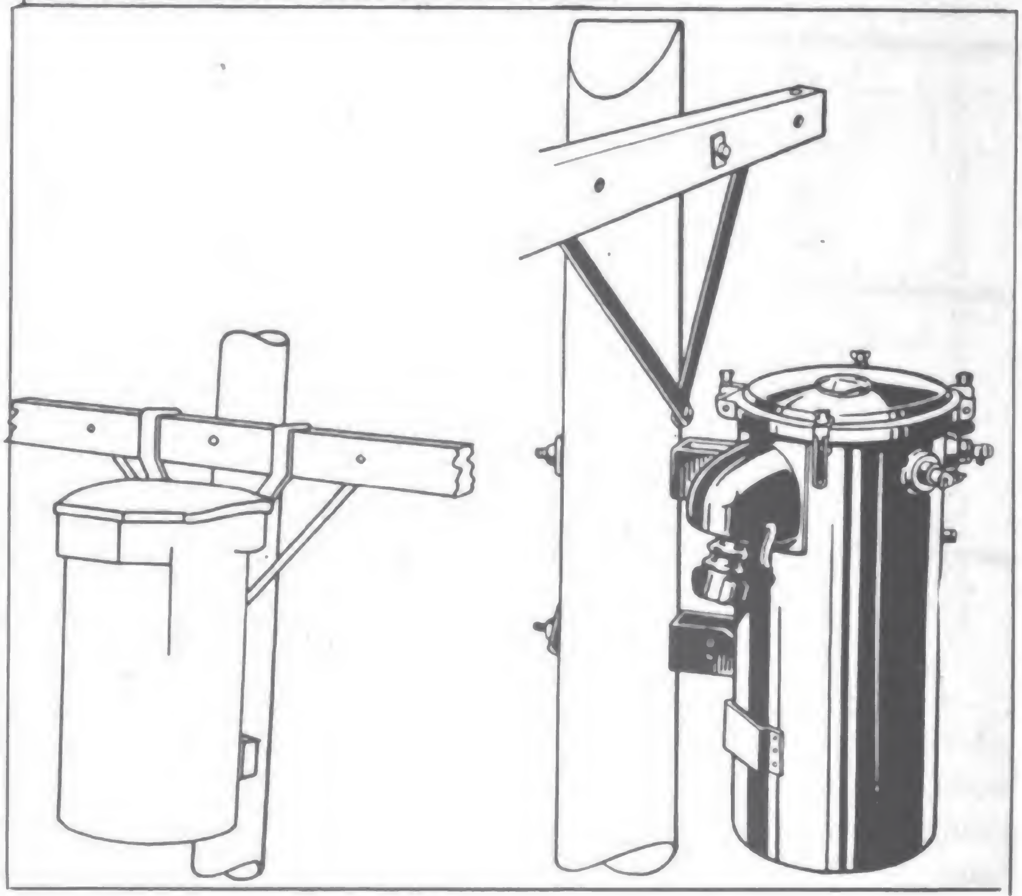


Figure 265.—Transformer mountings.

MOUNTING THE TRANSFORMER

The way you attach the transformer to the pole will depend on its design. The older type of transformers are hung on crossarms by means of a transformer hanger. The newer transformers are attached to a pole-mounting bracket that is bolted directly to the pole. Both methods are shown in figure 265. Notice that in each case, a crossarm is mounted directly above

the transformer. This crossarm has the job of supporting the lightning arresters, fuse cutouts, and jumper wires.

PRIMARY CUT-OUT FACTS

With the transformer in position, your next step is to connect it between the primary and the secondary wires. Two views of a typical transformer installation are shown in figure

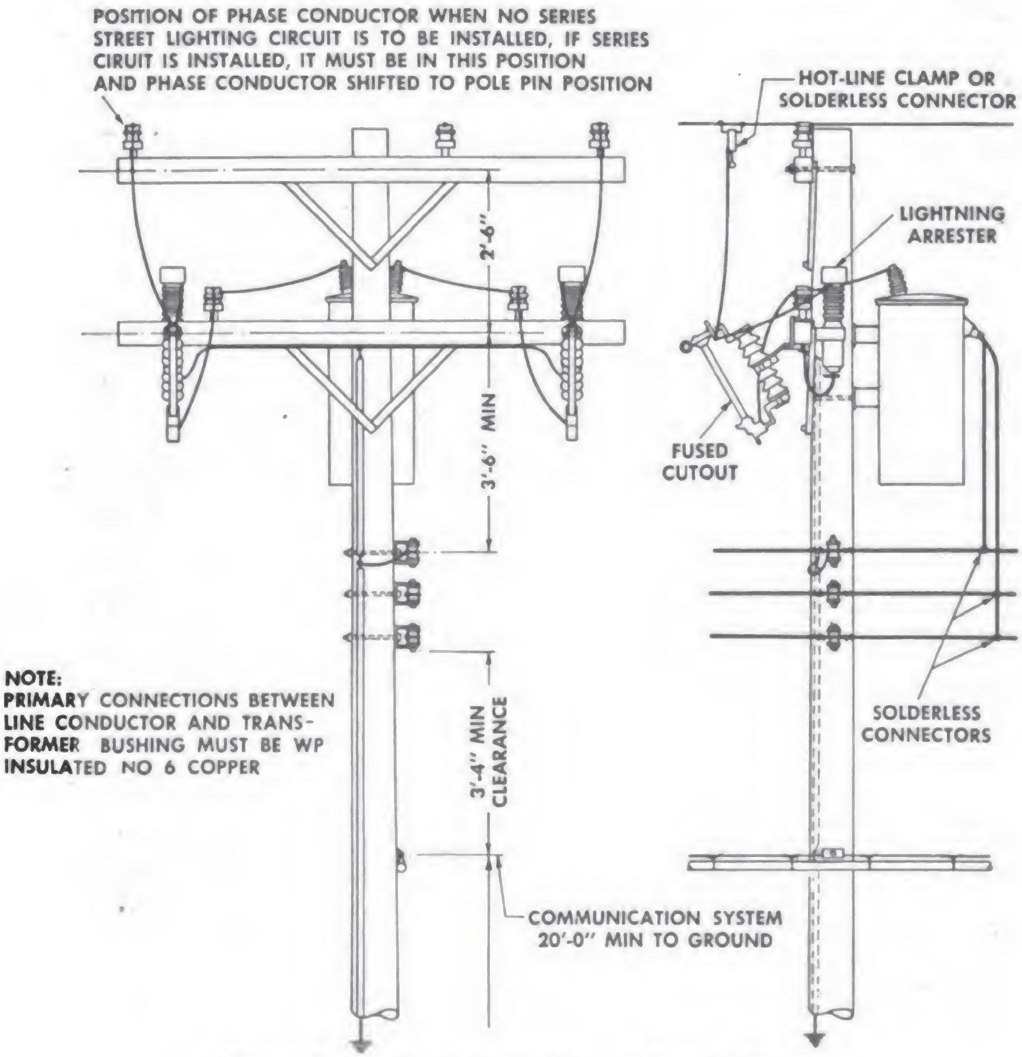


Figure 266.—Typical transformer installation.

266. Notice that a lightning arrester and a fuse cutout are placed on each end of the crossarm.

They fit in special type brackets which are clamped to the crossarm.

There are many types of fuses used in distribution systems. But they all have one purpose—to protect the transformer against overloads and shorts. The principal element in the fuse is a strip of metal. This metal is purposely made weaker than the rest of the line. It will melt or "blow" when the current exceeds a rated value.

The fuses used in the primary circuits are termed primary cutouts. The one in figure 266 is an automatic type. When it is in the position shown, the primary feeder is connected directly to the transformer through the fuse. An overload will cause the fuse to blow. This action forces the tube to drop out at the upper end and hang in an open position. The circuit will then be open between primary feeder and transformer.

Primary-Transformer Connections

A look at figure 266 will show you exactly how the primary cutouts are connected in the circuit. You can concentrate on just one of the cutouts, since the other is wired exactly the same. A drop wire is tapped onto the primary feeder and looped down and connected to the top of the cutout. From the bottom of the cutout, a wire is trained over and connected to the primary bushing on the transformer. The distance that the wire travels from the cutout to the transformer is long enough to require the support of a pin insulator.

Lightning-Arrester Facts

Overhead wires make a fine target for lightning discharges. The discharge is damaging because it causes very high voltages to appear on the wires. These high voltages, unless taken care of, will destroy the transformer and other equipment on the line. You can't prevent the lightning from striking the wire. But you can do the next best thing—by-pass the high voltage discharge to ground (earth) before it reaches the equipment. LIGHTNING ARRESTERS are the "valves" which do the job.

An overhead wire may be hit many times by lightning during the course of a storm. So you can expect a lightning arrester to be so constructed that it will act as an open circuit when the

line voltage is normal, and act as a short circuit to ground when a high voltage discharge takes place.

If you could slice through the outside porcelain body of the lightning arrester in figure 266, you would find two main parts. One part is called the SPARK GAP and the other the VALVE ELEMENT. They are in series with each other.

The SPARK GAP is formed by two metal electrodes facing each other across an air gap. That air gap is your open circuit when the line voltage is normal. But when the voltage zooms up due to a lightning discharge, the air gap breaks down and a spark jumps between the two electrodes. The spark presents an easy path for the current to follow. As a result, the lightning charge is quickly drained to ground.

The spark gap has one bad feature. It takes a high voltage to break it down, but it will continue to spark over at a voltage lower than the breakdown voltage. You can see the disadvantage in this. If the spark remains after the high voltage discharge disappears, it will offer a by-pass route to the normal line current. The line current will go to ground instead of to the equipment.

The VALVE ELEMENT acts to quench the spark after the high voltage has disappeared. It is placed in series with the spark gap. Thus, it will carry the same discharge current that passes through the gap. The element is made of material that offers low resistance to high voltages and high resistance to low voltages.

Here, then, is what takes place when lightning strikes. The spark gap arcs over, and the lightning-discharge current is drained to ground through the low-resistance valve element. When the high voltage dies away, the resistance of the valve element rises and prevents any more current from flowing through the arrester. The arc across the spark gap is snuffed out and the line is returned to normal.

Lightning Arrester Connections

You'll have to look back to figure 266 to get the points on arrester connections. The first thing you should notice is that the arresters are connected on the line side of the fuse cutouts.

If the arresters were connected on the transformer side, the fuses would blow each time the lines were struck by lightning.

A wire is connected between the top of the fuse cutouts and the top of the lightning arresters. This, in effect, connects the arresters to the primary feeders. A drop wire is tapped to the bottom of the arresters, trained along the underside of the crossarm and connected to the ground wire. The drop wire is secured to the crossarm with staples.

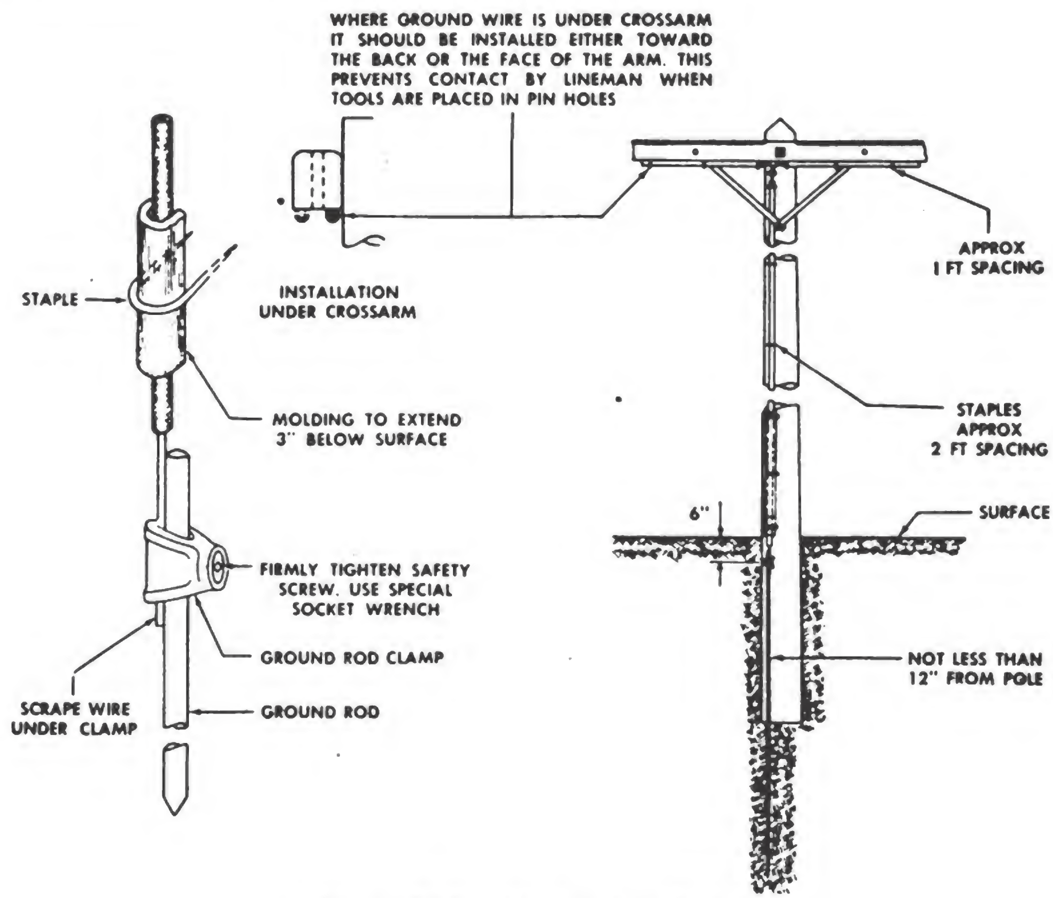


Figure 267.—Ground installation.

THE GROUND WIRE

The earth is at ground or zero potential. The lightning arresters must be connected to ground. Since the arresters are at the top of the pole and the earth at the bottom, you bring the two together with a GROUND WIRE.

Soft copper wire (No. 6 or No. 4) with a weatherproof insulation makes a good ground lead. It is attached to the side

of the pole with staples as shown in figure 267. Where possible, the first 8 feet of the ground wire above the ground should be covered with a wooden moulding. This is protection for personnel.

THE GROUND ROD

Of course you don't just stick the ground wire into the earth. A connection of that type wouldn't last very long. Besides that, you have to go plenty deep to get a low-resistance connection. Your best bet is to use a GROUND ROD.

The ground rod is usually about 8 feet long and made of copper-clad or galvanized steel. In a pinch, of course, you can use an old iron water pipe. The first step is to dig a hole at the point where the ground rod is to be installed. The hole should be about 6 inches deep. Next, start driving the rod into the ground with a sledge hammer. The rod should be set at a slight angle. Continue driving the rod until you have pounded it to the bottom of the hole. This puts the top of the ground rod 6 inches below the ground surface. Attach the ground wire to the ground rod as shown in figure 269. Tamp the dirt back into the hole.

THE SERVICE LEADS

The SERVICE LEADS are the last link in the distribution system. They bring the secondary voltage from the pole to the building. Get them up, tap them into the service-entrance conductors, and your job as a lineman is done.

Since the service leads are strung between pole and building, your first step will be to install supports. There's no problem at the pole because you can use the secondary racks which carry the secondary main. At the building, however, you are going to have to stop and take a look. The supports must be placed on the side of the building. And all buildings aren't constructed of the same material.

A FRAME building will be the easiest to work on. Where the service leads are not too large, individual supports for each lead may be screwed into the wall. The individual supports are called SERVICE INSULATORS. They are made of porce-

lain and have a hole in the body which makes it easy to dead-end the service lead. Figure 268 shows the steps in the installation of a service insulator on a wood building.

SOLID BRICK sides require a different method to hold the service support. A hole must first be drilled into the brick. Then a WOOD SCREW ANCHOR is inserted in the hole. The wood screw anchor is a partially split, tapered metal sleeve. The hole of the sleeve is threaded to fit the screw of the service support. When the support is screwed into the anchor, the sides of the anchor are forced apart and grip the sides of the brick.

HOLLOW TILE or cement blocks have thin sides. Neither a screw nor screw anchor will hold. You have to use a service insulator equipped with a threaded bolt. A TOGGLE is screwed onto the service bolt. The toggle is built somewhat like a wing nut. The wings of the toggle are pivoted so that they can be folded along the sides of the bolt. A strong spring on the toggle will force the wings out into a straight position when the pressure is released.

A hole is drilled through the outside wall of the tile. The service insulator bolt and toggle is inserted through the hole. When the toggle reaches the inside of the hollow tile, its wings will spring out and bear against the inside surface of the tile wall. All you have to do, then, is to turn the service insulator until it is tightly pressed against the wall of the building.

Figure 268.—Installing the service insulator.

Stringing the Service Leads

Your first step is to unreel the service leads on the ground between the building and the pole. Next, you dead-end the service

leads on the building service supports. A good picture of this step is shown in figure 268.

Now you're ready to tap the service leads into the secondary mains. The service leads may be pulled up the pole by hand. A typical service pole installation is shown in figure 269. This pole is serving two buildings. One set of service leads bears off to the left, the other to the right. Keep an eye on the service leads on the right.

Notice that the service leads are not tapped directly into the secondary mains. They are first tied to the secondary rack on the pole. This takes the strain off the tapped connections.

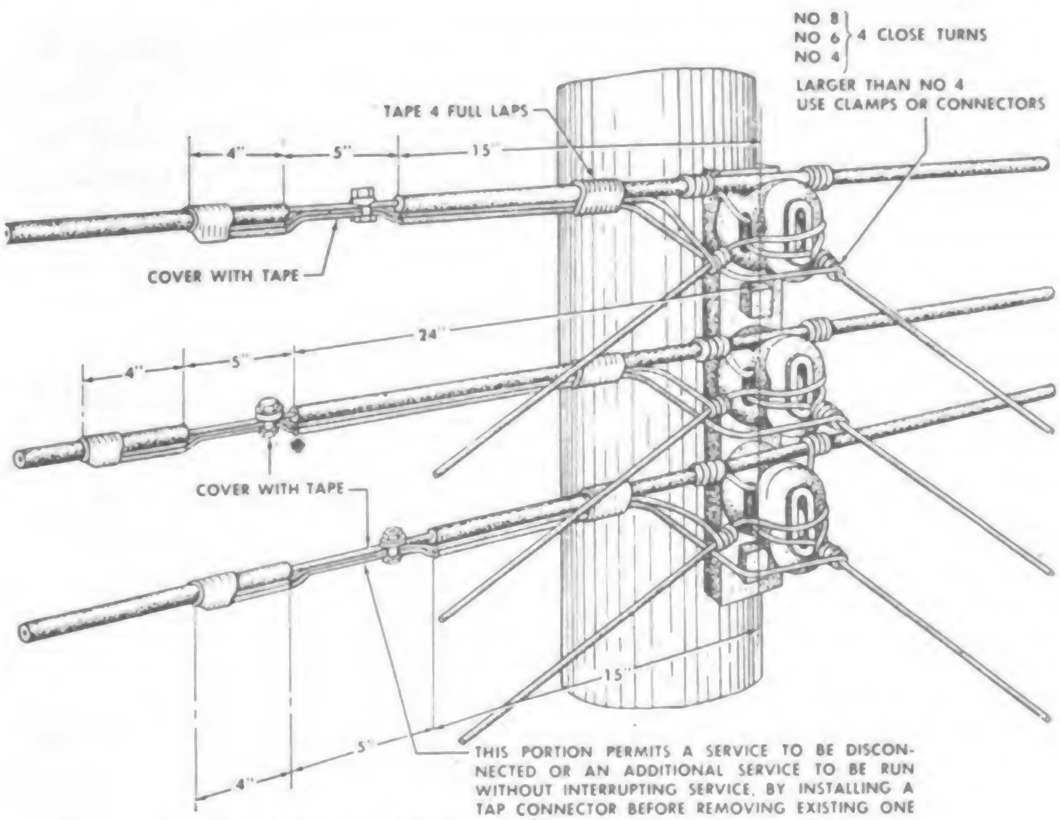


Figure 269.—Installing the service leads on the pole.

The lead is wound around the insulator. Then it is wrapped tightly about the main body of the lead and trained over to the point of connection on the secondary main. After the insulation has been removed from both secondary main and service lead, they are clamped together with a solderless connecter. Be sure that you restore the insulation with friction tape.

ELECTRIC SHOCK

Learning first aid for electric shock might seem a waste of time. But how would you feel if you had to stand by helplessly and watch your buddy die? Impossible? Don't kid yourself. It just takes one careless slip and the damage is done.

Need more convincing? O.K., suppose you happened to be the guy that got it. If everybody felt that first aid was a waste of time, you would soon be 6 feet under. So, read the following first aid instructions carefully and do a lot of practicing. It may save a life someday.

The Rescue

The first thing to do in case of electric shock is to remove the victim from the live circuit. But don't just rush in and try to drag him away. That will result in two victims instead of one. Instead, try to shut off the high voltage. If that is impossible, free the victim from the live conductor with a dry board, dry clothing or some other nonconductor.

The Treatment

Electric shock will usually stun the breathing nerve center at the base of the brain. As a result the lungs stop working and breathing ceases. Your job, then, will be to supply air to the lungs until the breathing center has recovered. You do this by ARTIFICIAL RESPIRATION.

The prone method of applying artificial respiration is shown in figure 270. Here are the steps to follow:

1. Loosen any tight clothing to permit free circulation. Lay the victim in a prone position, face down. Extend one of his arms directly overhead. Bend the other arm at the elbow so that his head will lie on the back of the palm. Turn the victim's face away from the bent elbow for free breathing space (view *A*, figure 270.)

2. Pry open the victim's mouth and remove any foreign substance, such as false teeth, gum, or tobacco. Keep the mouth open with the tongue extended. Be sure that the tongue is not drawn back into the throat.

3. Place yourself in a position astride one leg of the victim so that:

a. Your arms and thighs will be in a vertical position while applying pressure on the small of the victim's back.

b. Your fingers will be in a natural position on the back with your little finger resting on the bottom rib.

c. The heels of your hands will rest on the victim's back, as far apart as possible and still not slip.

d. Your elbows will be straight and locked (view *B*, figure 270).

4. Begin the artificial respiration by swinging forward and exerting a downward pressure. (view C, figure 270.) This motion should take 1 second. Release the pressure suddenly, and swing back to a sitting position on your heels. This motion should also take 1 second (view D, figure 270).

5. Rest 2 seconds and then begin your respiration motions again. It is important that you get and keep the correct cadence. Down and forward in 1 second, back to a resting position in 1 second, rest for 2 seconds. Try counting aloud in thousands. For example, one thousand and one, one thousand and two, etc.

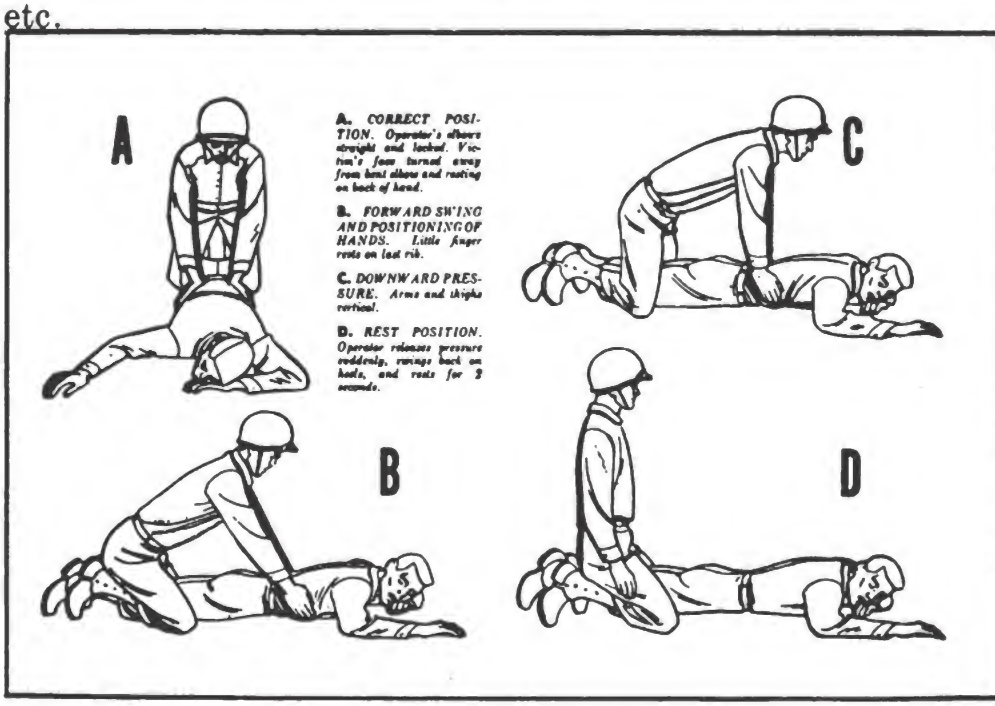


Figure 270.—Artificial respiration.

When the victim has regained his normal breathing, keep him lying quietly to prevent a nervous shock. Place him on his back with his head lower than the rest of his body. A blanket may be used for warmth, but don't wrap it tightly around him. KEEP A CLOSE WATCH UNTIL THE MEDICAL OFFICER ARRIVES.

SUMMARY

The four steps in stringing power lines are reeling out the wires, raising the wires to the crossarms, tensioning the wires, and tying the wires in.

Splices on hard-drawn conductors should always be made with solderless connectors.

Feeder lines, secondary mains, and service leads should always be tensioned to the proper sag.

All transformer installations should be protected with line fuses and lightning arresters. Line fuses or primary cutouts are placed between the transformer primary and the feeder line. Lightning arresters are placed between feeders and ground.

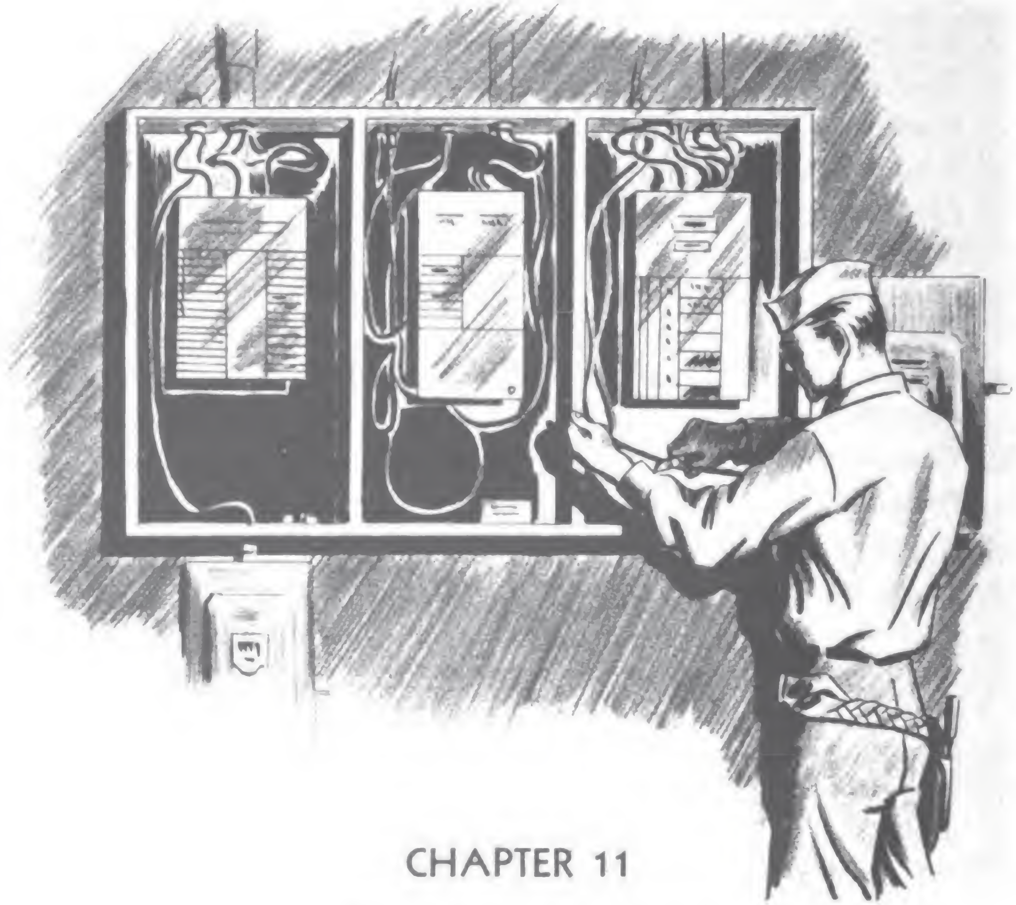
Lightning arresters are ground by a ground wire and ground rod.

The ground wire is attached to the side of the pole with staples and should be covered with a wooden moulding.

The ground rod should be driven at least 8 feet into the ground with its head 6 inches below the surface.

QUIZ

1. Give the four steps in stringing wire on poles.
2. Is solder used with the splicing sleeve?
3. Is annealed copper hard- or soft-drawn?
4. What is sag?
5. Name three methods of determining or measuring sag.
6. What is a secondary rack?
7. Give four steps necessary in the installation and connection of a transformer.
8. Give two items installed in conjunction with all standard-type transformers.
9. In what piece of power-line equipment will you find a spark gap and a valve element?
10. What is the purpose of the valve element?
11. Where is the transformer fuse placed in the power-line circuit?
12. How long is the average ground rod?
13. Where should the top of the ground rod be in relation to the ground surface?
14. What term is used to describe the power line between the building and the pole?
15. How is a service insulator attached to hollow tile?
16. What type of first aid is used when breathing stops because of electric shock?



CHAPTER 11

INTERIOR WIRING

SOMETHING TO THINK ABOUT

Flipping a switch to turn on a light or start a motor doesn't take a lot of brainwork. You've probably done it a thousand and one times and not given it much thought. But the next time, suppose you stop to consider why that motor starts or the light burns.

It all begins, of course, back at the GENERATING STATION. That's where the voltage that pushes the electrons through the motor winding and light filament is developed. The gap between generating station and the building which houses your electrical equipment is bridged by the wires of the DISTRIBUTION SYSTEM. These wires bring the correct voltage needed to run

the motor and energize the light right up to the side of the building. The INTERIOR WIRING SYSTEM takes over at that point. Its job is to feed the electric power to the lights and motors scattered throughout the building.

WHAT TO EXPECT

Wiring the inside of a building involves more than just stringing wire. First of all, personnel must be protected against shock. So you can expect a grounding system. Second, you want the wiring system to last. That means using the proper-size wire and shielding the wire with some sort of protective covering. Then there's the equipment to worry about. It must also be protected and controlled. This involves the use of fuses and switches. And last but not least, you must have some definite wiring plan to go by.

THE WIRING DIAGRAM

Before you start to wire a building, you should get an over-all picture of the wiring layout. This is done with a WIRING DIAGRAM. Now, here's a point you should understand. The wiring diagram does not show where the lights, switches, and other electrical devices are actually placed in the building. Rather, it shows the proper CONNECTIONS of the wiring system. Symbols are used as a shorthand method of indicating electrical devices. The lines represent the wires which carry the electric power to the devices.

THE SERVICE ENTRANCE

You can get to work immediately by looking at figure 271. It's a diagram of the interior wiring system of a small building. The best place to start tracing the wires is outside thc building. This is the point where the interior wiring system connects to the service leads of the outside distribution system. It is called the SERVICE ENTRANCE.

Notice that the service entrance is fed with a SINGLE-PHASE THREE-WIRE system. The value of the voltage between the two outside wires is 230 volts. The voltage between any one of the outside wires and the middle, or neutral wire, is 115 volts. This set-up allows you to operate electrical devices rated at

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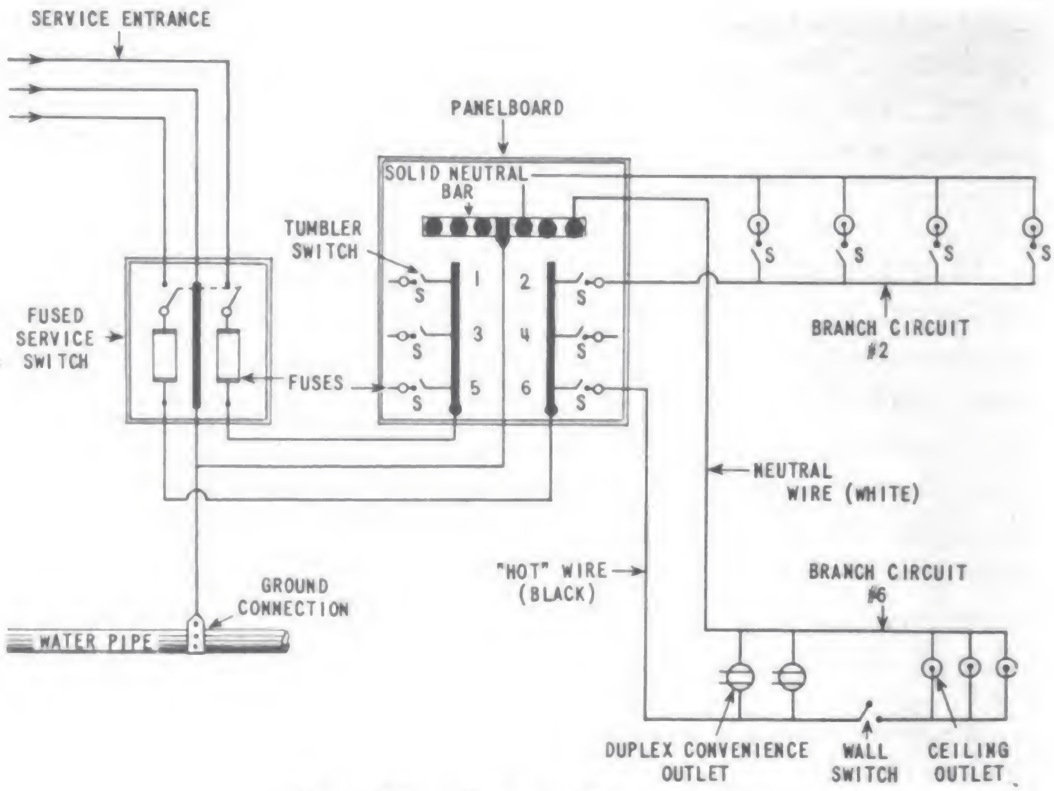


Figure 271.—Interior wiring diagram.

either 230 volts or 115 volts. For example, a 230-volt single-phase motor may be connected between the two outside wires. A 115-volt light can be tied between the neutral wire and one of the outside wires.

SERVICE ENTRANCE TO SERVICE SWITCH

Now let's get back to the service entrance in figure 271. Three wires are tapped onto the outside service leads and enter the building through a metal pipe. After entering the building, the wires are trained over and connected into a SERVICE SWITCH. The wires running between the switch and the outside of the building are termed the SERVICE-ENTRANCE CONDUCTORS.

There's nothing unusual about the service switch. It consists of two hinged copper blades that work together. In the ON position, the blades are inserted in series with each of the outside wires and form a continuous circuit. In the OFF position, the blades are pulled open and cause a break in the line.

What's the purpose of the service switch? Well, notice that

all incoming voltage and current must first pass through the switch before feeding to the electrical devices in the building. Opening the switch cuts off the power from ALL parts of the interior wiring system. Make a beeline for the service switch in any emergency. It also comes in handy when repairs on the interior wiring are necessary.

SERVICE FUSES

There's always the chance of an overload developing in the interior wiring system. All it takes is a shorted motor or defective wiring. Of course, the service switch is always handy to break the circuit. But you may not be around when the short develops. And even if you were, most of the damage would be done before you could reach the switch.

All this calls for the use of a device which will AUTOMATICALLY open the circuit when the current goes above its rated values. This device is known as a FUSE. The fuse consists essentially of a metal link which becomes part of the wiring system when inserted in the line. The link is made of a low-melting alloy. It is the first part of the wiring system to melt when the current rises above normal value. When the link melts, the circuit opens, and the current stops flowing.

Each outside wire of the service switch in figure 271 contains a fuse. This particular type is known as a CARTRIDGE fuse. The fuse link is placed inside a fiber cylinder with metal caps at each end. The link extends between the metal caps. When inserted in the circuit, the fuse is held in place by spring clips which grasp the metal ends of the fuse.

All parts of the service switch, including fuses, are placed in a metal box. A hinged cover is placed over the front of the box. The only time you'll need to open the service switch is when you replace a fuse. The switch itself, can be operated by a handle which extends through the side of the box.

GROUNDING THE NEUTRAL

You may have noticed something unusual about the service-switch connections in figure 271. If you've missed it, take a close look at the middle wire. Still don't see anything? Well

how about that middle wire which goes directly through the switch? That should set you to thinking. After all, the two outside wires are broken at the switch, why not the middle one, too?

To get the answer, you'll have to trace the middle wire after it leaves the switch. It splits off in two directions. One wire bears off to the right. The other comes straight down and connects to a water pipe. The water pipe acts as a grounding rod, since it is buried in the ground outside the building.

Connecting the middle wire to the water pipe brings the voltage on the wire down to a zero or ground potential. It becomes a neutral wire which may be safely handled without danger of shock. Since the neutral wire is not a live wire, there is no need to break its circuit at the service switch. Remember, no matter where the neutral wire is used in the interior wiring system, it is always at ground potential.

NEED FOR THE NEUTRAL WIRE

A neutral wire protects personnel from accidental electric shock. Some electrical devices which you will operate may have their working parts exposed. A good example of this is the common electric light socket. Examine the wiring and you'll find two leads entering the socket. These leads bring in the 115 volts necessary to energize the light bulb when it is placed in the socket. One lead is connected to a center contact button in the socket. The other lead is connected to the threaded copper shell of the socket.

The light-bulb base is just a light socket turned inside out. It consists also of a center contact button and a threaded copper base. The filament in the bulb is connected between these two points. Screwing the bulb in the socket places the filament across the 115 volts.

Now, suppose you start to screw the bulb into the socket. Just about halfway in, your hand slips and touches the metal base of the bulb. The base of the bulb is in contact with the shell of the socket. If the shell is connected to a live wire you will find yourself between a high voltage and ground. A shock might result. But if the neutral wire is connected to the shell,

there's nothing to worry about. It is already at ground potential and nothing happens.

Using a neutral wire has another advantage, too. Where a live or "hot" wire and a neutral wire are used to feed voltage to an electrical device, a switch will be necessary only in the live wire circuit.

SERVICE SWITCH TO PANELBOARD

You've brought the wires from the service entrance to the service switch. The neutral has been grounded. Now you're ready to distribute the electric power to the motors and the lights (keep an eye on figure 271).

The three feeder wires, including the neutral, are brought over to a PANELBOARD. The panelboard is a jumping-off point or distribution center. It is a convenient spot from which the proper voltages may be directed to the motors and lights.

Notice the way the feeder wires are connected inside the panelboard. Each of the two hot wires connects to a vertical copper strap. The neutral wire connects to a horizontal copper strap. You have thus set yourself up three points from which to obtain the voltages for your branch circuits.

BRANCH CIRCUITS

The branch circuits are the last link in the interior wiring system. They bring the electrical energy from the panelboard to the lights and motors. The number of branch circuits radiating out from the panelboard depends on the number of lights and motors in the building. You see, the current which each branch circuit may carry is limited by the size of wire used. The Navy requires the use of a No. 12 wire. It can carry a current of 20 amperes safely. Thus, the lights fed by any particular branch must not draw more than 20 amperes when all are turned on.

Motors are usually hooked up to their own branch circuits. That's because they draw such a large current when starting. Where there are a large number of motors, a separate panelboard is used to distribute the power to them. This panelboard is termed a power panelboard. The one for lighting purposes is called a LIGHTING PANELBOARD.

Branch Circuit No. 6

Take a look at figure 271 again to find out exactly how the branch circuits are laid out. Notice that the panelboard is set up for six branch circuits, but that only two are shown. This makes it easier to explain the principles of the circuits.

First, let's take branch circuit No. 6. It consists of two wires. One wire comes from the neutral bar, the other from the live bar. The live or hot wire does not connect directly to the live bar. A fuse and switch separates the two. The switch is the simple tumbler type which can open or close the live-wire circuit. The fuse works on the same principle as all other fuses. It is the PLUG TYPE which screws into a socket. Since the branch circuit should not draw more than 20 amperes, the fuse is rated at this value.

Trace the hot wire down and you'll find it connects directly to one side of a pair of DUPLEX CONVENIENCE OUTLETS. The neutral wire connects to the other side of the outlets. You've probably used duplex convenience outlets and never known their exact name. They are usually placed on the wall, near the floor. Their purpose, of course, is to provide a convenient spot to plug in portable lamps, drills, etc. Notice the symbol used to denote a convenience outlet.

The hot wire and the neutral wire continue on from the convenience outlets over to three CEILING OUTLETS. A ceiling outlet is the point where you connect your ceiling fixture. A WALL SWITCH breaks the hot wire circuit. With the switch open, all three ceiling lights will go off at the same time. Closing the switch puts them all on.

Branch Circuit No. 2

Branch circuit No. 2 starts out from the panelboard in the same manner as branch circuit No. 6. Notice that a tumbler switch and plug fuse is inserted in the hot line.

The neutral wire and the hot wire travel over to four ceiling outlets. The light in each outlet is controlled by a separate wall switch.

You might be wondering why each light in branch 2 has a separate switch, while all three lights in branch 6 are controlled

by a single switch. The answer is that the wiring diagram doesn't give the complete picture. Remember that it only shows the wiring connections. A little farther in the chapter you'll be given a floor plan of the building. And then you'll see that each of the lights of branch No. 2 is located in separate rooms. The three lights of branch circuit No. 6 are grouped together in one room.

There's one more point that should be brought to your attention. Notice that the neutral wire and hot wire in both branch 2 and 6 are color-coded. This makes it easy for you to identify the neutral wire and the hot wire when making connections. The outer covering of the neutral wire is colored white or gray. The hot wire has a black-colored insulation.

ADDED FACTS

You've been given the wiring diagram of the interior wiring system in a small building. Naturally, this won't be the only wiring diagram you will use. There are all types of buildings with different electrical layouts.

For example, the service entrance in figure 271 is fed with 3-wire single-phase power. This is perfect where you have only lights and single-phase motors to operate. But if there are three-phase motors in the building you can expect an additional three-phase service entrance. Again, in some instances, you'll have a building equipped with only a small number of lights. You will find that a 2-wire single-phase service entrance is all that is necessary.

The panelboard in figure 271 is typical. There are many others you will run across. Some have a circuit breaker in each branch circuit, instead of a tumbler switch and plug fuse. Others have just the plug fuse. But the PRINCIPLE of all interior wiring systems can be found in the wiring diagram of figure 271. So be sure you know how to read it. The others will then be as easy as rolling off a log.

INTERIOR WIRE PROTECTION

Cutting, threading, bending, and installing pipe might seem strictly for the pipe fitter. And they would be if the pipes were part of the water system. But where they are used to protect

the wires of the interior wiring system, then they become part of your job as a Construction Electrician.

Installing wires in pipes makes good sense. Not only are the wires protected from mechanical abuse, but the possibility of an electrically caused fire is reduced to a minimum. Then, there's the advantage of being able to replace wires or make changes without ripping out the walls.

Of course, it means double work for you. The pipe must first be installed and then the wires pulled through. But it pays off in the long run with an interior wiring system that will last as long as the building—and that's what really counts.

HALF THE BATTLE

You've won half the battle of learning to be an electrician when you become familiar with the materials and tools used

Figure 272.—Conduit wiring material.

in your work. As you read the descriptions given below, be sure to check figure 272 to obtain a good picture of the materials.

Conduit

Conduit is the electrician's term for the pipe in which the wires of an interior wiring system are installed. The conduit is measured in terms of its inside diameter, and ranges in size from ½ inch to 4½ inches. The number and size of wires to be installed in the conduit will determine the size of conduit used. It is similar in appearance to gas pipe, but is made of soft steel. This makes it easier for you to bend the conduit to fit the contour of the walls in the building.

You will work with two types of conduit—RIGID CONDUIT and ELECTRIC METALLIC TUBING or thin-wall. You won't find any difference in the inside diameter measurement of thin-wall as compared to rigid conduit of the same size. That means thin-wall tubing will carry the same number of wires as rigid conduit. A difference does lie, however, in the thickness of the walls of each type. Rigid conduit is thick enough to be threaded. Thin-wall has a thickness about 40 percent that of rigid conduit and should never be threaded.

You'll receive both rigid conduit and thin-wall tubing in 10-foot lengths. The rigid conduit will be threaded at each end, and a coupling included on one end only. Both the thin-wall and rigid conduit are protected against corrosion. Either a zinc or black enamel coating (inside and out) is used on rigid conduit. Thin-wall will only have a zinc coating.

Thin-wall is lighter and is easier to bend than rigid conduit. Because of its thinness, however, you will have to take greater care in bending to prevent flattening or kinking of the tube. Thin-wall is never used where it will be exposed to a great deal of mechanical injury.

Outlet Boxes

The branch wires carry the current from the panelboard over to the switches, convenience outlets, and lighting fixtures. The branch wires are protected most of the way by conduit. But when they reach the spot where a switch, outlet, or lighting

fixture is to be placed, then the conduit stops and an OUTLET BOX takes over.

The outlet box is a small, galvanized steel box. It serves two purposes. First, it acts as a support for the switch, outlet, or lighting fixture. Second, it provides a small chamber to hold conveniently any splices which may be necessary.

Outlet boxes are classed according to shape—square, octagon, and rectangular (figure 272). Generally, you'll use the square and rectangular boxes for switches and convenience outlets, and the octagon box for lighting fixtures.

The conduit must actually enter the outlet box. But you don't have to go to the trouble of drilling a hole. Each outlet box is provided with a number of partially punched disks or KNOCK OUTS. All it takes to remove the disk is a sharp blow with a ball-peen hammer and a twist with a pair of pliers.

Junction and Pull Boxes

Question: When is an outlet box not an outlet box? Answer: When it is used for a JUNCTION or PULL BOX. Sound like double talk? Well, actually it isn't, because the cover that is placed on the box will determine its use. For example, you may have a subbranch circuit that is to be tapped off the main branch line. At the tapping point you would need a splicing chamber. So, you install a box that uses just a plain metal cover. Then, it becomes a JUNCTION BOX.

A look at figure 273 will probably help to clear things up. It shows a run of conduit feeding a few convenience outlets mounted on a work bench.

The conduit comes up through the floor, enters two junction boxes, and then continues on to the outlet boxes. The cover plate on one junction box has been removed. You can get a good view of the spliced wires inside the box and the method of bringing the conduit into the box. The cover of one of the outlet boxes has also been removed. Notice that the difference between junction box and outlet box lies only in the cover used.

Bushings and Locknuts

The knockout holes in the outlet boxes and other thin-walled housings are threadless. So, the rigid conduit cannot be fas-

tened to the boxes by screwing it in. But, since the end of the conduit is threaded, a BUSHING and LOCKNUT may be used (figure 272).

Figure 274 shows how the locknut and bushing appear on the conduit after installation. Securing the conduit to the

Figure 273.—Outlet and junction boxes.

box is simple. First, screw the locknut onto the threaded conduit end. Next, insert the end of the conduit through the

knockout hole into the box. Now, screw the conduit bushing on the end of the conduit as far as it will go. Last, screw the locknut tightly against the side of the box. A pair of 10-inch gas pliers, preferably with angled jaws, provides all the leverage you'll need to install the bushing and locknut.

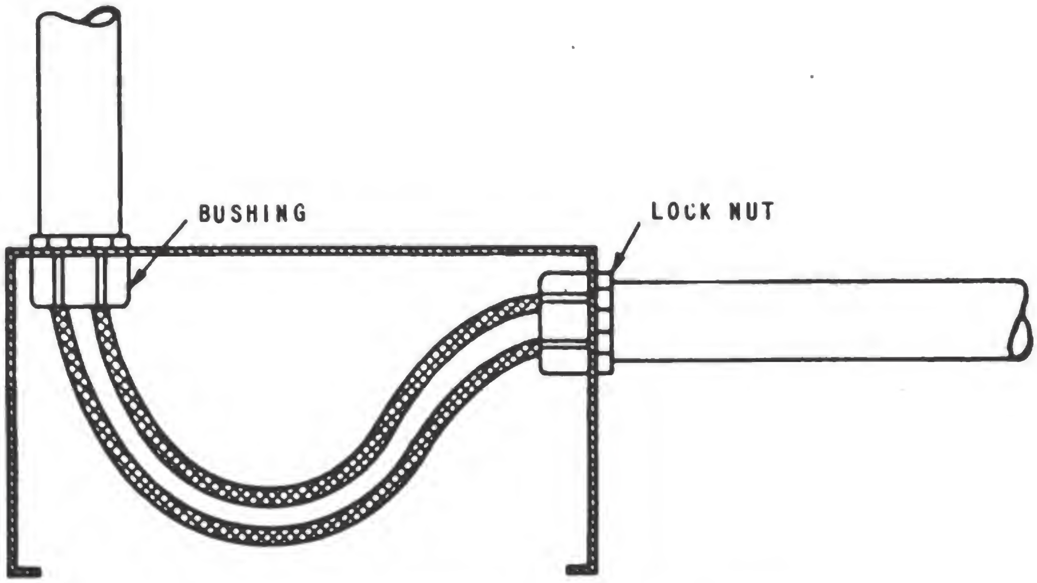


Figure 274.—Bushing and locknut installation.

Threaded Couplings

Where one length of rigid conduit is to be joined to another, the ordinary pipe COUPLING is used to hold the two securely together. The coupling itself is a short hollow metal cylinder, threaded on the inside. Its inside threads are cut to the proper size to receive the outside threads of the conduit.

Figure 275 shows how two lengths of conduit are brought together with a coupling. In view *A*, the coupling is being screwed tightly on the threaded end of the first length of conduit. A pipe wrench holds the conduit steady, while another wrench provides the turning force on the coupling. In view *B*, the second length of conduit has been inserted in the coupling and is being tightened up with a wrench.

Fittings

Regular manufactured FITTINGS are sometimes substituted for junction and pull boxes. These fittings come in a variety of

styles, but most common is the L -type. An L-type fitting permits a change of 90° in the direction of the conduit run (figure 272). There are two companies that make these fittings, so you'll call them by two trade names—CONDULETS and UNILETS. These fittings, by the way, should only be used on exposed conduit runs. Their smaller size, as compared to the junction box, makes for a better-appearing installation.

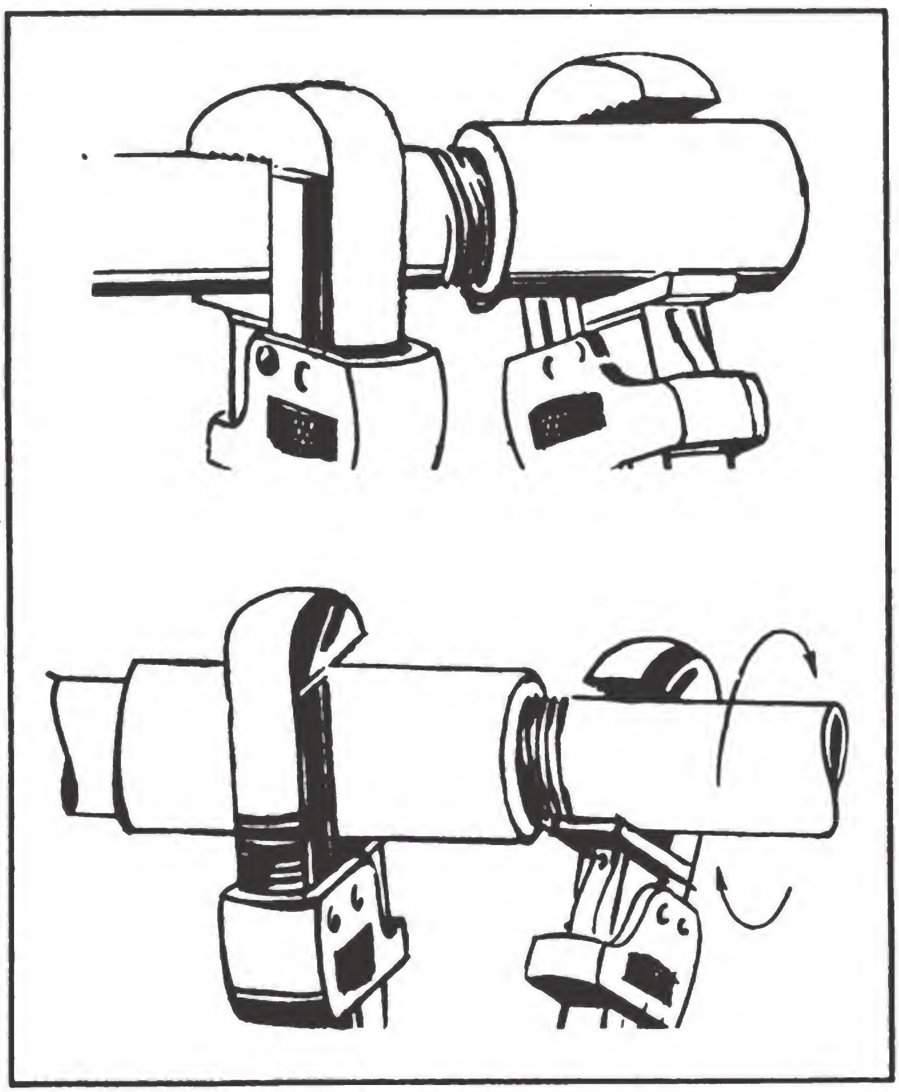


Figure 275.—Conduit coupling connection.

In figure 276, you can see an L-type fitting installed on a conduit run. The fitting, in this case, is used as a connection between a length of conduit attached to the side of the wall and

a piece of conduit extending through the wall. The cover of the fitting has been removed so you can see the branch wires in the conduit.

It shouldn't be hard to figure out why an opening is needed for the L fitting. It would be almost impossible to install wires

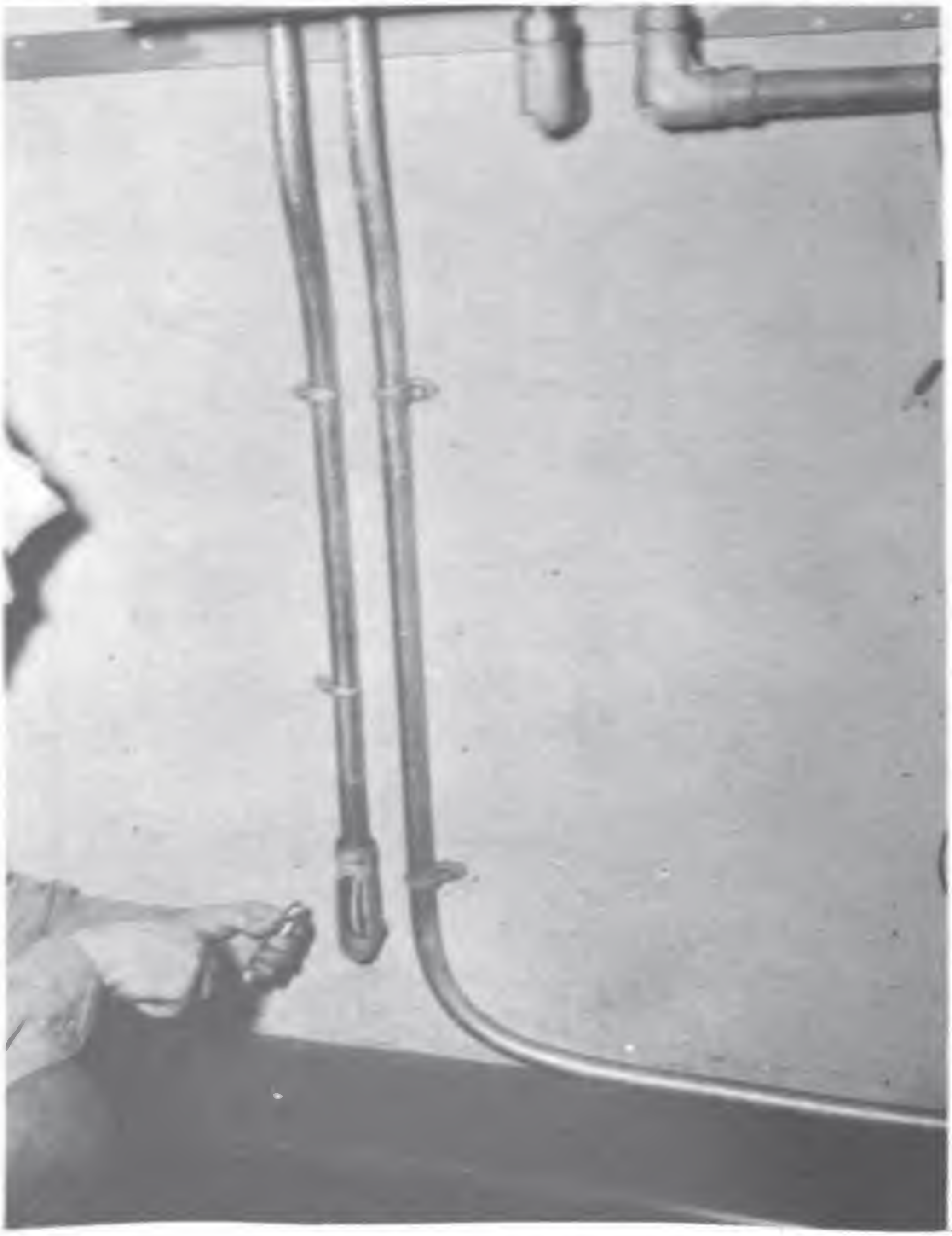


Figure 276.—L-type fitting.

through the sharp 90° bend of the fitting if there were no opening available to help fish the wires through.

Pipe Straps

Pipe straps are a common form of conduit support when the conduit must be installed on a flat surface. Pipe straps are used in both conduit runs in figure 276. The method of securing the straps will depend, of course, on the composition of the surface or wall. If the surface is wood, lag screws or wood screws are used. Brick, stone, or concrete walls will require a drilled hole and expansion bolts. In hollow walls, toggle bolts must be used.

CUTTING THE CONDUIT

You will have to be able to cut conduit to definite lengths to meet the needs of your installation. Either a HACKSAW or a PIPE CUTTER can be used. A PIPE VISE holds the conduit during the cutting process.

It will take a little practice before you get the hang of cutting conduit properly. As far as the hacksaw is concerned, remember that it's the forward stroke that does the cutting and not the backstroke. The blade teeth point forward, so use pressure on the forward stroke only. And don't forget to use long steady strokes at just a normal rate of speed

Where the hacksaw may be used to cut any metal shape, the pipe cutter has been specially designed to cut pipe or conduit only. The pipe cutter has an adjustable cutting wheel and two pressure rollers. The lower view of figure 277 shows how to use the pipe cutter. The first step, of course, is to fasten the conduit in the vise. In the next step, place the cutter in position on the pipe. Do this by sliding the cutter over the conduit until the cutter wheel is on the mark where the conduit is to be cut. Then you tighten the cutter handle until the cutter bites slightly into the conduit. The third step consists of the cutting operation. For each complete turn of the cutter around the conduit, adjust the bite of the cutter wheel by tightening the handle no more than one quarter of a turn. You repeat this procedure until the conduit is cut.

REAMING THE CONDUIT

Hacksaws and pipe cutters always leave a sharp ragged edge inside the conduit. These burrs would do a lot of damage to the insulation of the conductors installed in the conduit. So, you have to do something about it. The tool that you use to remove the burrs is called a REAMER. It is a conical-shaped tool with

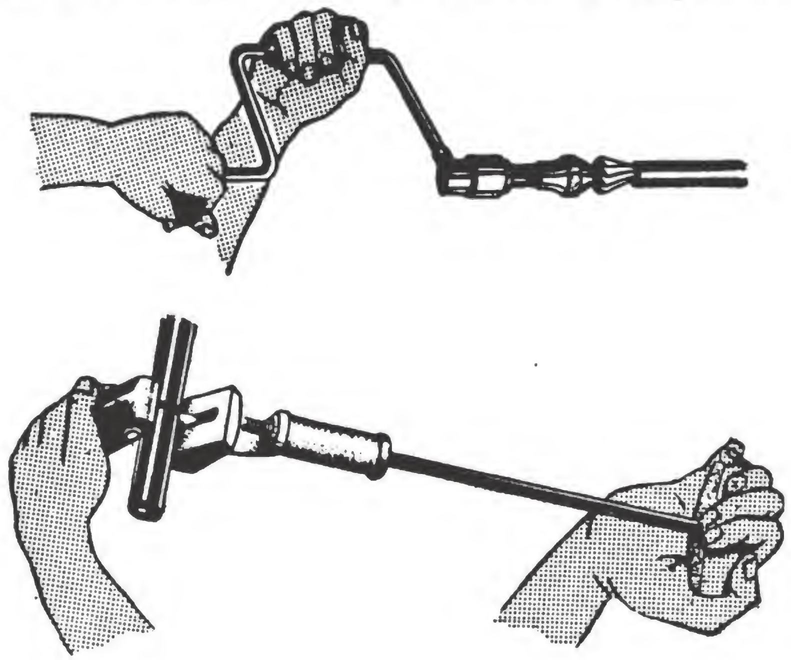


Figure 277.—Cutting and reaming pipe.

sharp-edged flutes. The reamer is held and turned by a bit brace as shown in the upper picture of figure 277. In a pinch the conduit may be reamed with a rat-tail or half-round file.

THREADING THE CONDUIT

You've cut the conduit to fit into a definite space. If the conduit is to be secured with threaded connections it will be necessary to thread the newly cut end. The tool used to cut the threads is called a DIE. It is supported in a metal housing or STOCK. A BUSHING acts as a guide to make certain the thread will be cut straight. Long handles, attached to the stock, provide sufficient turning leverage. A ratchet-type hand threader is shown in figure 278. The stock is turned in one direction by moving the handle forward and backward in a short arc.

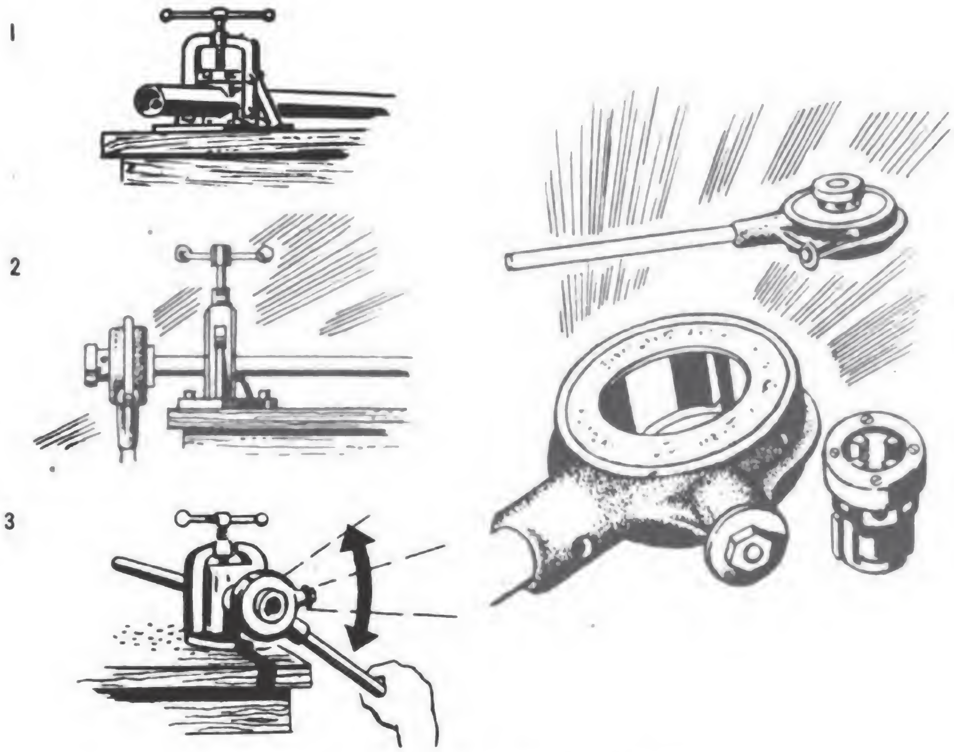


Figure 278.—Threading conduit.

The steps in threading a piece of conduit are also pictured in figure 278. Here's how you go about it:

1. Secure the conduit in the vise. The end to be threaded should project about 8 inches beyond the bench.
2. Slide the stock over the conduit until the conduit bears up against the die.
3. Exert a forward pressure on the stock as you turn it, until the die begins to cut into the conduit surface. After that, this pressure will not be needed. The die will draw itself up the conduit over the threads it cuts. You can stop threading after one or two threads show beyond the stock.

Two precautions will make your job easier and neater. First, be sure that the handle of the stock is kept at right angles to the conduit. Second, apply thread-cutting oil to the thread, die, and conduit every two or three turns.

BENDING THE CONDUIT

Conduit should be run as direct and straight as possible.

But there will be spots in the installation where a bend in the conduit will be necessary. No matter how you make the bend, it is bound to resemble one of the three types shown in figure 279. The bend in the conduit nearest you is called a SADDLE bend. The conduit in the middle has an OFFSET bend. A NINETY or right-angle bend is being made in the conduit at the top of the picture.

Where small-size conduit is to be bent, you will find nothing more useful than the HICKEY as a bending tool. That's what the electrician in figure 279 is using. Large-size conduit must be bent with a hydraulic bender.

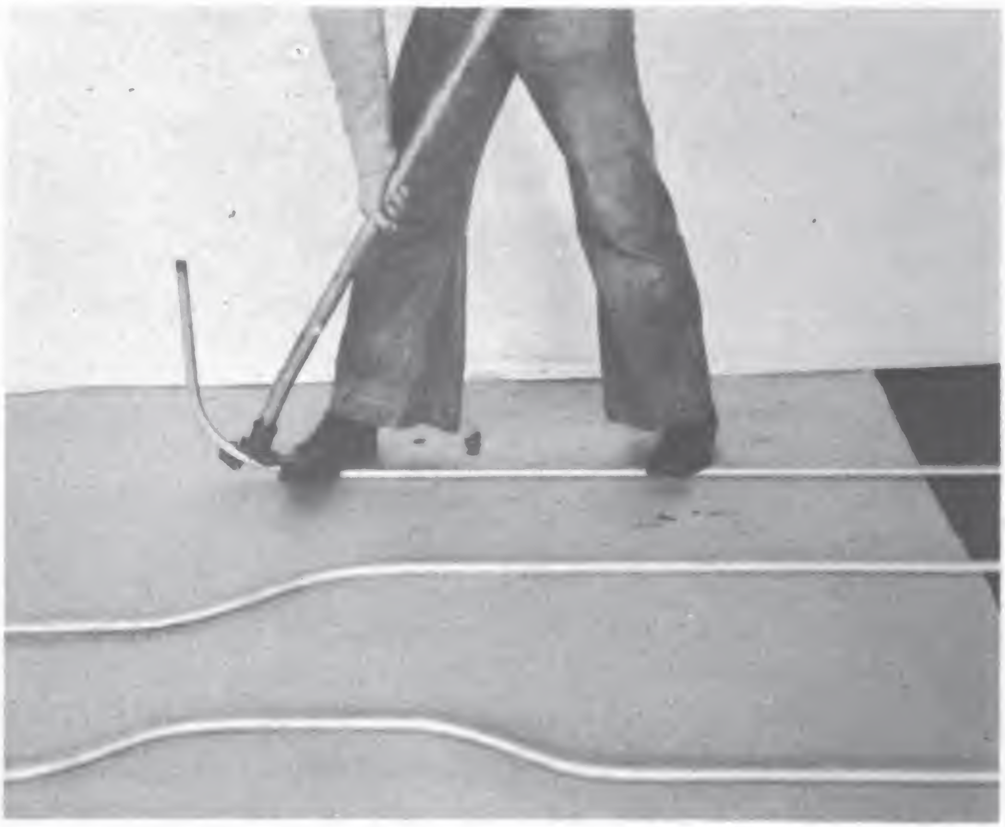


Figure 279.—Conduit bends.

Making a Ninety

Bending conduit is like any other job that requires a certain amount of skill—anyone can learn how to do it with practice and a knowledge of the principles involved. The practicing is

up tc you, but you'll find the principles of making a 90° bend in figure 280.

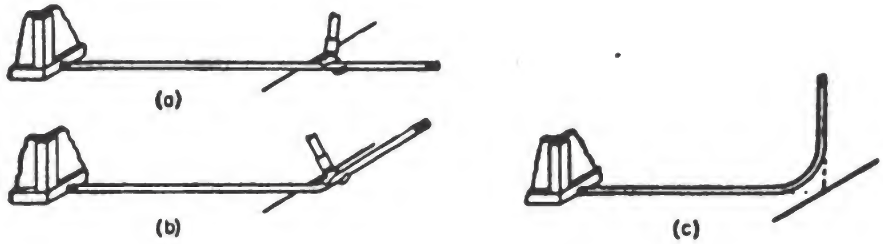


Figure 280.—Making a 90° bend.

In this case, suppose you want to make a 90° bend 72 inches from one end of the conduit. The first thing you do is measure 72 inches from the wall and make a mark on the floor. Then, butt one end of the conduit up against the wall with the other end extending past the mark on the floor. Slip the hickey over the conduit about 2 inches beyond the mark (view *A*). Place your foot on the conduit and pull down on the hickey until about a 30° angle is formed. Slip the hickey on the conduit to a point directly over the mark on the floor and make another 30° bend. Next, move the hickey on the conduit about 2 inches behind the mark and complete the 90° bend. When you are through, the raised end of the conduit should be vertically alined with the mark on the floor (view *C*).

THE ELECTRICAL PLAN

At the beginning of this chapter, you learned the fundamental workings of an interior wiring system. A wiring diagram (figure 271) helped you along by showing you the connections of fixtures and outlets in two branch circuits. But that's as far as it went. To find out just where the fixtures and outlets are placed in the building you will have to use an ELECTRICAL PLAN.

The electrical plan in figure 281 is a working drawing of the wiring diagram in figure 271. The building is actually a two-story structure, but all you will be concerned with is the first floor plan. As you look at the drawing, you see a top view of the building with the roof and second floor removed. You can

see that the first floor has been partitioned off into three offices, a storeroom, and an outer office.

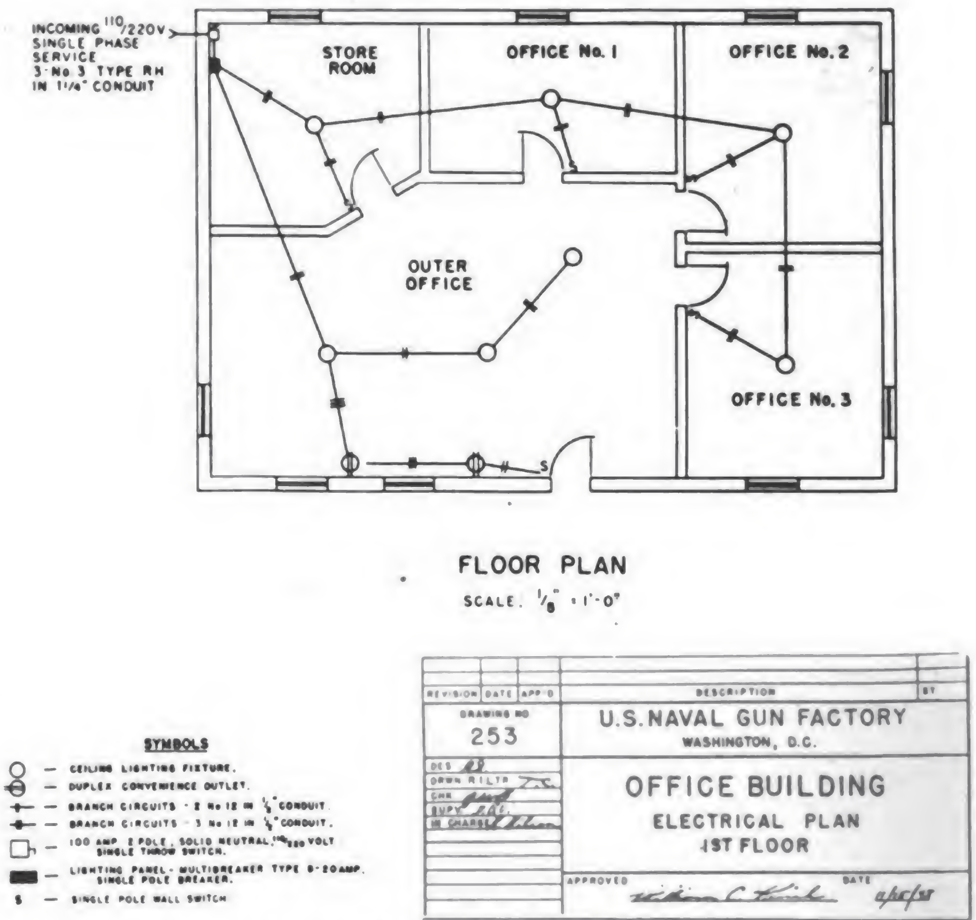


Figure 281.—The electrical plan.

Now, what does the electrical plan tell you? Well, for one thing, it indicates what material is needed. For instance, there's a white and black square in the upper left corner of the storeroom. A look at the descriptions under the heading "Symbols," tells you that a white square is the symbol for a service switch, and a black square a lighting panelboard. The specifications, in this case, call for a 2-pole solid-neutral service switch, and a 6-branch 20-ampere lighting panelboard.

The solid lines which run between the fixtures, outlets and panelboard represent the conduit. The small perpendicular

marks across each conduit line indicate the number of wires installed in that particular section of conduit. The two lines radiating from the panelboard tell you there are two branch circuits. These, of course, are branch circuits Nos. 2 and 6 shown in the wiring diagram of figure 271. One branch circuit feeds a light outlet in the storeroom and each of the three offices. A wall switch to control each light is placed near the door of each room. The other branch circuit feeds three light outlets controlled by one wall switch, and two convenience outlets, all located in the outer office.

SERVICE INSTALLATION

Using the electrical plan in figure 281 as a guide, you are ready to make the conduit installation. The first thing you will do is install the service switch and lighting panelboard in the storeroom. They must be mounted securely to the wall about 5 feet from the floor. Your best bet is to use a large board for the mounting surface. The board is fastened to the

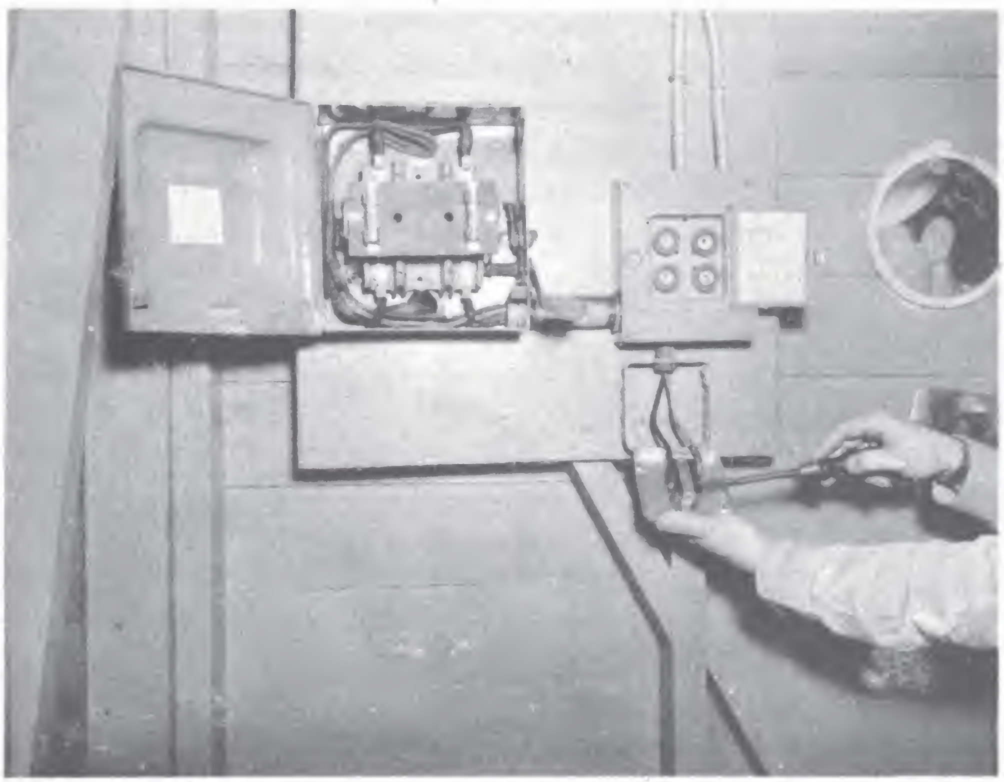


Figure 282.—Service installation.

wall with lag screws or anchor bolts. Then the service switch and panelboard boxes are mounted on the board with wood screws (figure 282).

If the installation is to be concealed—that is, where the building is newly constructed and only the framework has been set up—mount the service switch and panel board boxes between the studs of the framework. A short board (header) connected between two studs may be used as the mounting surface. Be sure, in this case, that the boxes are mounted so that their front edges will be flush with the wall when it is completed.

CEILING OUTLET BOX INSTALLATION

The ceiling outlet boxes which hold the lighting fixtures are next on your installation list. Your first step is to spot the boxes. That is, you determine exactly where the outlet boxes are to be placed on the ceiling. The general location can be taken from your electrical plan since it is drawn to scale.

Before the boxes are mounted, the conduit entry holes should be prepared. The proper number of knockouts which are removed from each box depends, of course, on how many conduits enter the box. This information can be obtained from the electrical plan. For example, the ceiling outlet in the storeroom has three conduits entering it. So you will remove three knockouts.

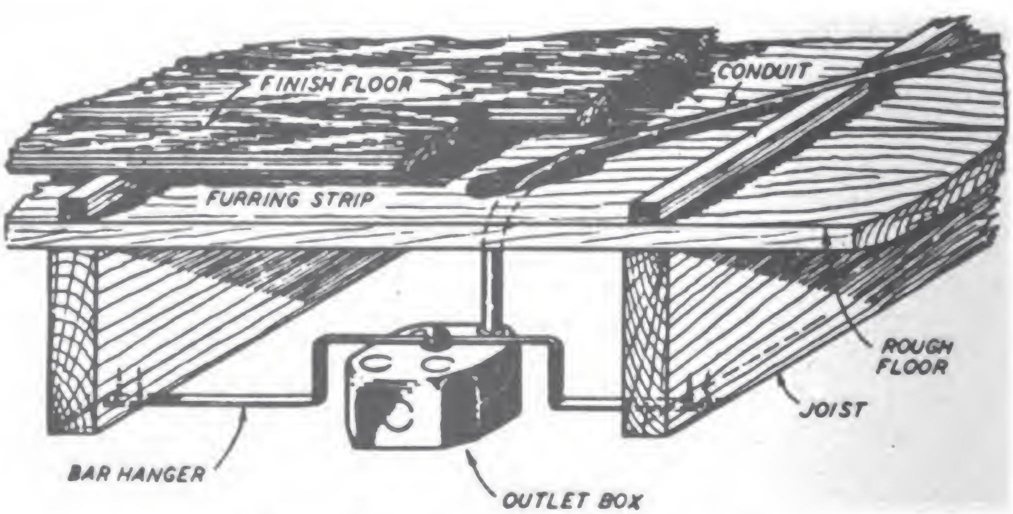


Figure 283.—Ceiling outlet installation.

The method of securing the ceiling outlet to the ceiling depends on the building. If the installation is exposed, the outlet box is fixed directly to the ceiling. If the installation is concealed, the outlet box is secured to a metal bar hanger that is mounted between the joists of the ceiling framework. This type of installation is shown in figure 283.

To secure the outlet box to the bar hanger, it will first be necessary to remove the center knockout in the bottom of the box. The box is then slipped onto a threaded fixture stud which is attached to the bar hanger. A locknut screwed onto the fixture stud will clamp the outlet box to the hanger. The fixture stud also serves as a support for the lighting fixture which is to be hung from the outlet.

WALL OUTLET BOX INSTALLATIONS

Installing the boxes for your convenience outlets and wall switches is your next job. First, be sure that the proper number of knockouts are removed from each box to permit entry of the conduit runs.

The electrical plan calls for two convenience outlets in the outer office. The exact spot to place the two boxes can be read from the plan. The Navy requires that convenience outlets be placed 12 inches from the floor. Be sure the boxes are mounted securely. The same advice goes for the switch boxes which are mounted by the side of each door. A switch box should be placed 48 inches from the floor.

RUNNING THE CONDUIT

The last step in your installation work is the running of the conduit. Your electrical plan will tell you HOW the conduit is to be connected between the different boxes, but it won't indicate the exact route the conduit must take. That is up to you, and will depend to a great extent on the structure of the room. Remember, the Navy requires that conduit be installed PARALLEL WITH OR AT RIGHT ANGLES TO THE BUILDING WALLS. They must also be supported properly by pipe straps or by other approved methods.

An example of this can be taken from the conduit run between

the service switch and the first ceiling outlet in the outer office. In the electrical plan in figure 281 this conduit run is shown as a straight line between the two points.

Actually, here is the way you would make the run (follow it along in figure 284):

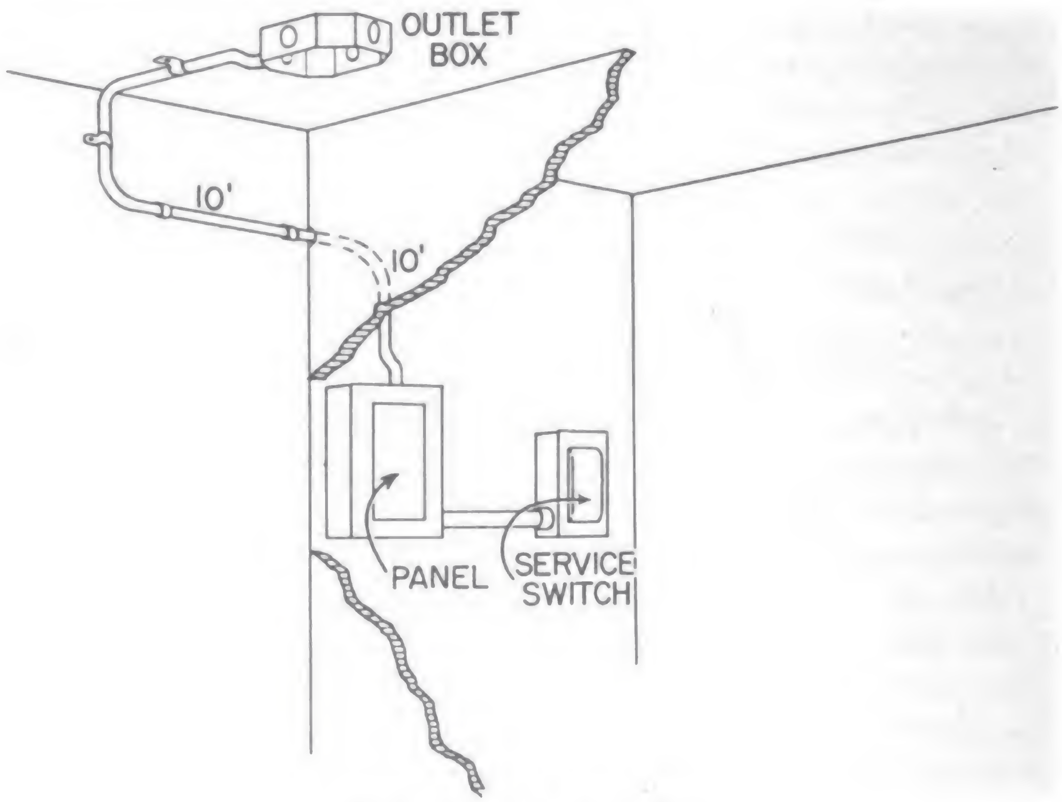


Figure 284.—A conduit run.

1. You would start out at the service switch and bring the conduit vertically up the side of the wall to a point about 12 inches below the ceiling.
2. You would then make a right-angle bend in your conduit and run it against the wall in a straight line parallel to the ceiling.
3. You would continue this run through the partition separating the storeroom and the outer office.
4. At a point on the wall opposite the ceiling outlet you would make a right-angle bend up to the ceiling. Then you would make another right-angle bend to point the conduit in the direction of the outlet.

5. You would finish up the run by extending the conduit along the ceiling over to the ceiling outlet.

In your conduit installations, always bear in mind that wire will be pulled through the conduit. So, you must never make more than four 90° bends in one conduit run. Also, do not place 90° bends too close together. Place a length of conduit (10 feet) between them, if possible. And last, but not least, keep kinks out of your bends.

INSTALLING THE WIRES

With the conduit system in place, you are all set to install the wires. The number of wires placed in each conduit run can be checked with the electrical plan.

You can't expect to be able to PUSH a set of wires through a long run of conduit—especially if there are a number of right-angle bends. The only solution is to PULL the wires through. To do this, employ a FISH TAPE. Fish tape is a steel tape about one quarter of an inch wide with a hook at each end.

Suppose you want to pull the wires through the conduit run between the service switch and the ceiling outlet in the storeroom (electrical plan, figure 281). You start your fish tape at the ceiling outlet and keep feeding it through until the hooked end comes out at the service switch box. The two branch wires

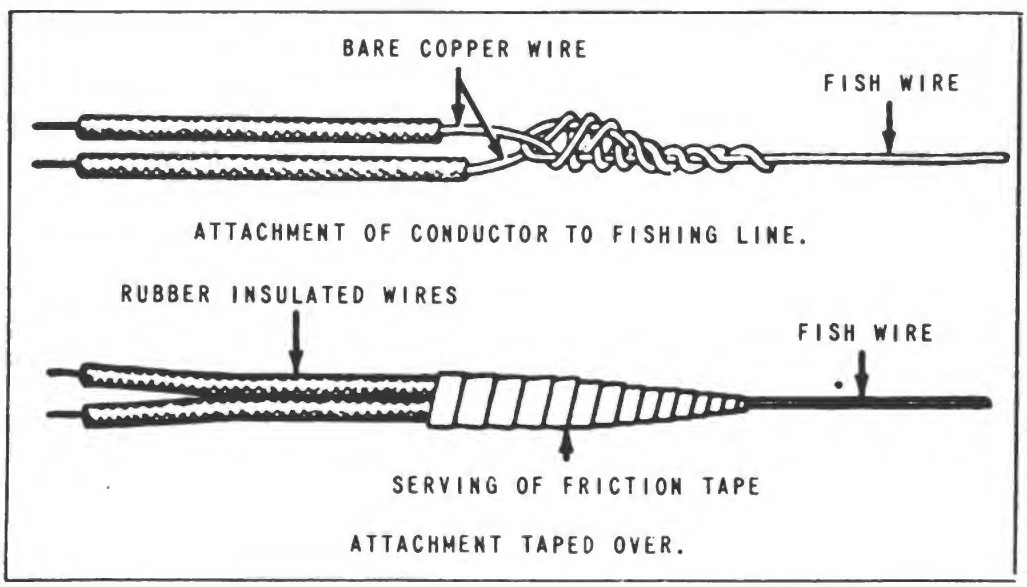


Figure 285.—Fastening wires to the fish tape.

to be installed in the conduit are tied to the fish tape as shown in figure 285. Then you pull the fish tape back and the wires will come with it. It is always best to station a man at the point where the wires enter the conduit run. He can feed the wires in without kinks or twists.

In installing the wires, always be certain that the number of conductors in each run conforms to the electrical plan. It is also important that you install the correct color-coded wire. Remember that fixture and convenience outlets are tied between a neutral and hot wire, and a switch is placed in the hot wire circuit only. So, you can expect black and white coded conductors to enter fixture and convenience outlet boxes, but only black wires to be brought into switch boxes.

FINISHING UP

After the wires have been installed throughout the conduit system, you will connect them to the fixtures, convenience outlets, and switches. At the same time you will complete any splicing which may be necessary.

FIXTURES come in many styles, sizes, and shapes. But no matter which type you are installing, there are two main steps. One, you support the fixture by attaching it to the fixture stud in the ceiling outlet box. Two, you complete the electrical circuit by splicing the branch wires to the fixture wires.

One type of fixture installation is shown in figure 286. Here, the fixture is attached to the fixture stud by a special type of coupling—sometimes called a hickey. Notice that the two fixture wires are spliced to the branch wires and completely insulated with rubber and friction tape. A soldered pigtail splice is used. Remember, when you're splicing the wires, white is connected to white and black to black.

In figure·282, a duplex convenience outlet is being installed. Notice that in this case, the bakelite body of the receptacle is fastened to the plate or cover of the outlet box. Where a rectangular box is used, attach the receptacle body directly to the box. The plate cover is then attached to the receptacle. The branch wires are fastened to screw terminals on either

side of the receptacle. Be sure the bare wire is wrapped around the terminal post in the direction in which the terminal screw tightens.

Rectangular boxes are generally used to hold snap switches. So, when you install the wall switch, fasten the switch to the

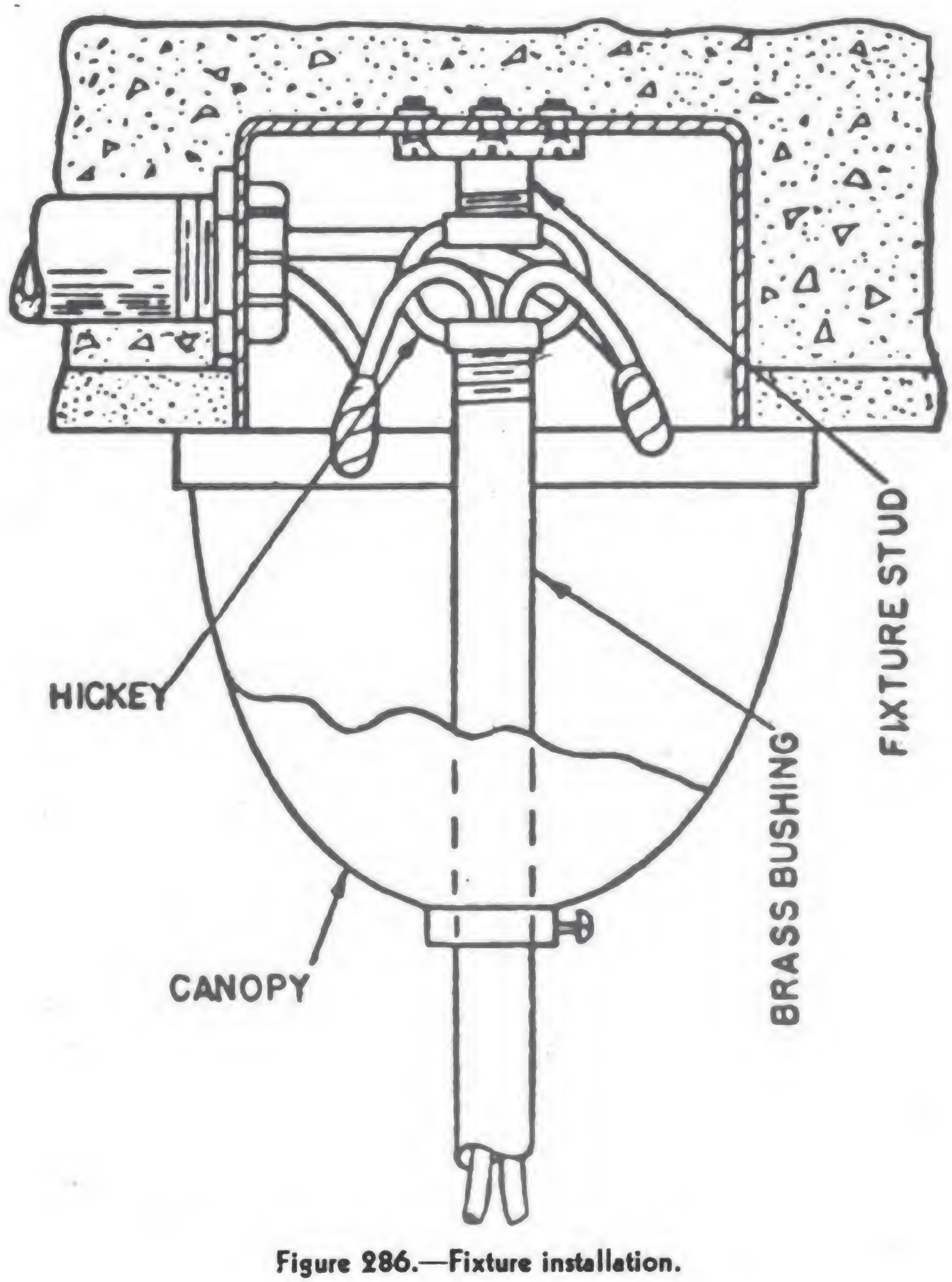


Figure 286.—Fixture installation.

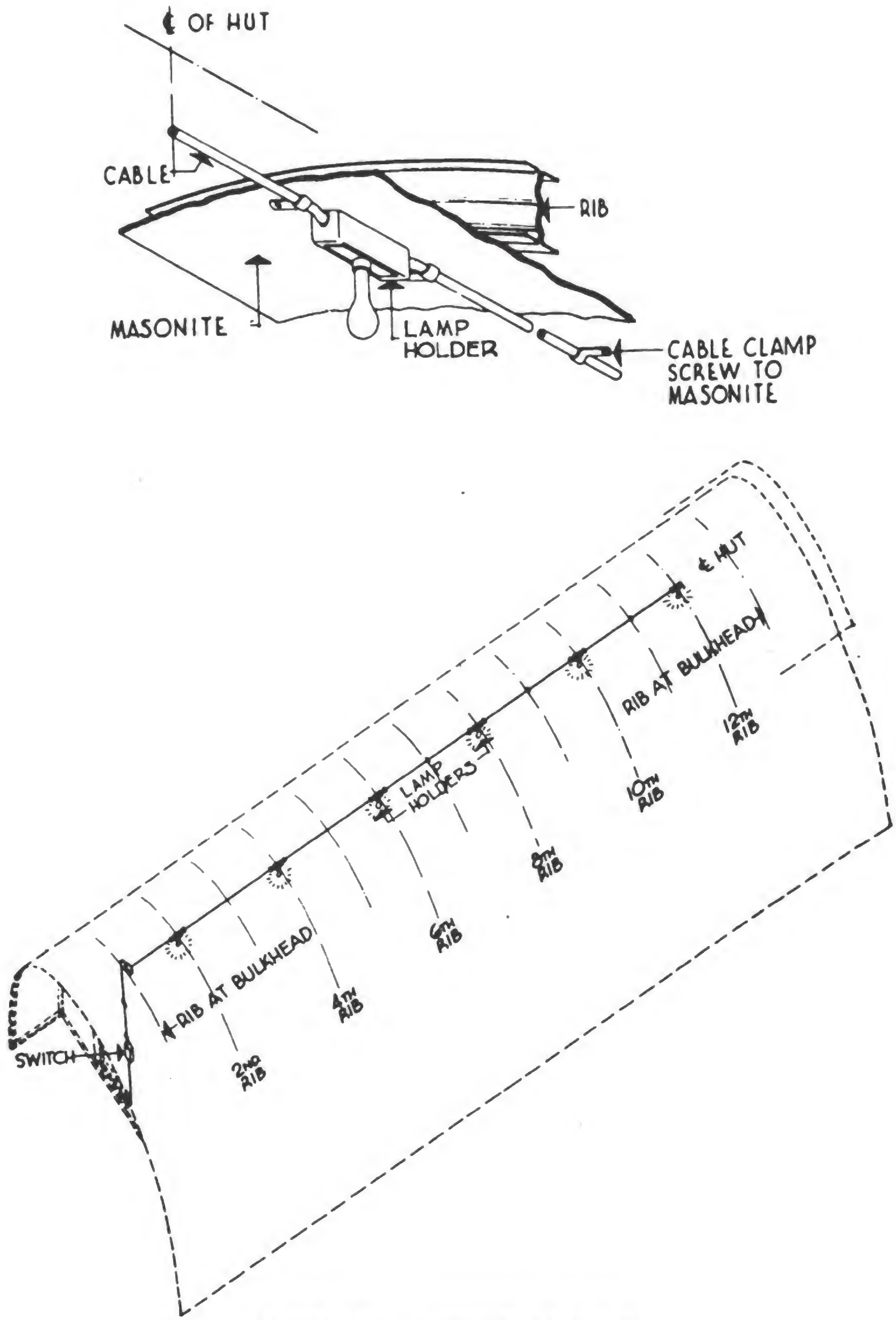


Figure 287.—Quonset hut wiring.

box. The switch plate will then be screwed to the switch body. Screw terminal points are usually used for the wire connections.

QUONSET HUT WIRING

A quonset hut is a temporary prefabricated building. Because of the nature of its design you wouldn't expect a permanent conduit installation to be used. That doesn't mean, though, that the wires are unprotected. They will have a protective covering, the composition of which depends on the type of wire used. The two main types are NONMETALLIC SHEATHED CABLE (Romex) and ARMORED CABLE (BX).

NONMETALLIC SHEATHED CABLE is rubber-insulated wire enclosed in a protective braid covering which has a high resistance to moisture, flame and mechanical injury. A simple quonset-hut lighting installation using Romex is pictured in figure 287. The system consists of a lighting circuit extending lengthwise at the top of the hut, with a switch at the doorway. An enlarged view of the lampholder circuit shows you how the Romex is installed. The lampholder itself is not fastened to the ceiling. It is supported by the Romex which is secured to the masonite ceiling with cable clamps.

ARMORED CABLE, or BX, is insulated wire protected by a flexible metal cover. To run armored cable is easy because its flexibility allows it to be bent by hand. And, where rigid conduit must have a coupling at least every ten feet, armored cable can be run uninterruptedly from outlet box to outlet box. Since the armored cable cannot be threaded, special types of clamp connectors must be used.

SUMMARY

There are three distinct components of the electrical system at a naval base:

1. The generator or power plant supplying the electricity.

2. The distribution system bringing the electricity to the building.

3. The interior wiring system distributing the electricity within the building.

A wiring diagram is used as a quick simple method of showing the exact electrical connections.

The service entrance conductors join the interior wiring system and the distribution-system wires coming from the pole.

The service switch is primarily a DISCONNECT SWITCH.

The purpose of a fuse is to protect the equipment and wiring system from damage when trouble develops.

The panelboard is used to distribute small loads of electricity to the various circuits and give fuse protection to each.

One wire of the interior wiring system is grounded for the safety and protection of personnel and equipment.

After pulling the wires into your conduit attach only white wire to white wire and black wire to black wire.

When properly installed the white wire is at zero potential—it won't shock you. But the black wire is hot—so handle it with care.

A branch circuit is that portion of the wiring system which extends beyond the last fuse or overcurrent device.

The Navy requires that you use No. 12 wire or larger on your interior wiring system unless you receive special permission.

Unless otherwise specified the interior wiring system is to be run in RIGID conduit.

Boxes, conduit, and panelboards must be securely mounted and all joints tight.

Don't install boxes where they won't be accessible after the building is finished.

Measure, cut, ream, thread, bend, and install your conduit, then fasten it securely at least every 4½ feet.

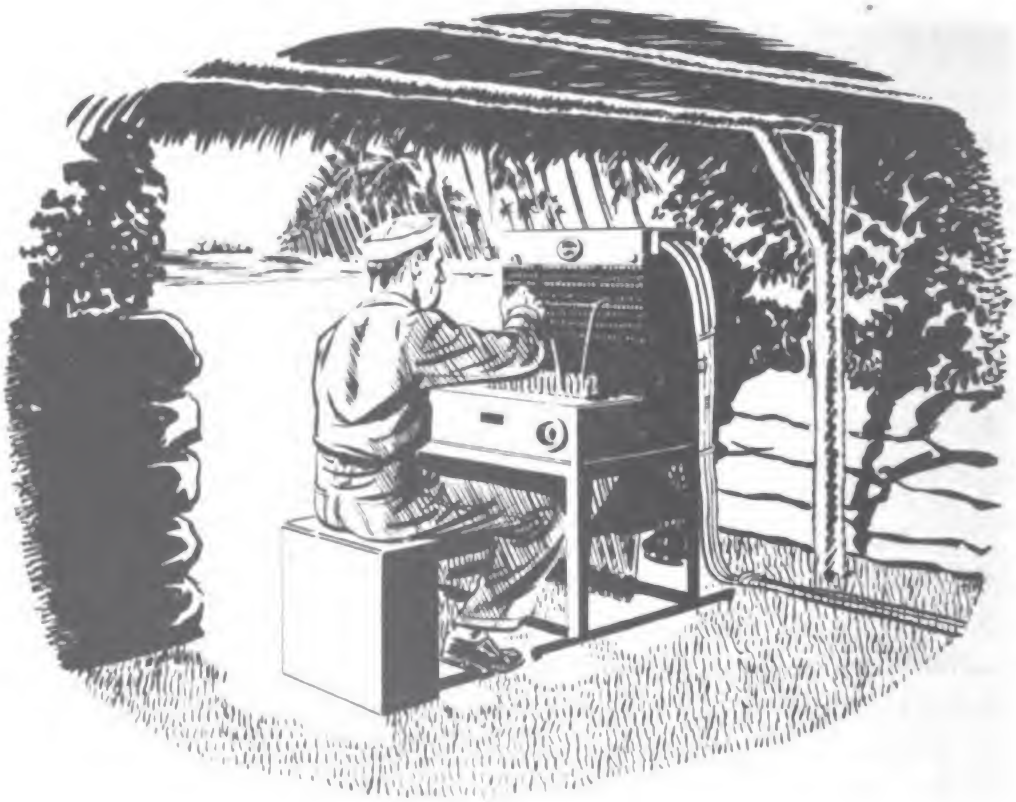
It is a two-man job to pull wires in conduit. Don't spoil a good job by attempting to do it alone.

Be sure that all splices are neatly and securely soldered and taped. Ninety-five percent of branch-circuit wiring shorts are traceable to poor box connections.

Many Navy buildings are wartime structures which have temporary types of wiring such as BX, Romex, and thin-wall conduit.

QUIZ

1. What information may be secured from the blueprint or electrical plan?
2. What are the names of the items to which each end of the service-entrance conductors are attached?
3. Are the fuses in series or parallel with the incoming lines?
4. Why is a wire run down and tapped to the water pipe?
5. Name three functions that are served by having a panelboard.
6. What is the minimum-size wire which may be used for branch circuits in the Navy?
7. In a 110-volt single-phase two-wire system, what are the colors of the ground or neutral wire. The hot wire?
8. Name two types of conduit.
9. What two items are used to secure a piece of threaded conduit to an outlet box?
10. Where may condulets and unilets be used?
11. What is used to secure pipe straps to concrete?
12. Why is conduit always reamed after it has been cut?
13. What is a hickey?
14. What are the names of the three most common types of conduit bends?
15. What is the bolt called which holds the ceiling outlet box to the bar hangar and also supports the fixture?
16. How far from the deck do you place wall switches?
17. What is the greatest number of 90° bends that may be placed in one conduit run?
18. What tool is used to pull wires through conduit?
19. What are the two most common types of cable used in quonset huts?
20. Where in an installation should the conduit contain two black wires and no white wires?



CHAPTER 12

TELEPHONE COMMUNICATIONS

LOGS, PIGEONS, OR TELEPHONES

How you engage in a conversation with another person depends upon the distance between you and that person. If he's within shouting distance, you can let your vocal cords do all the work. But, if he's out of range of your voice, then you've got to use other means. Beating out a message on a hollow log is one way. And of course, you could send a carrier pigeon. However, since hollow logs and pigeons aren't regular Navy issue, you'd probably find it lots handier to use a TELEPHONE. Besides being rugged and reliable, the telephone has the added advantages of secrecy and simplicity of operation.

THE BASIC SYSTEM

A telephone system is composed of many telephones connected together by a network of wires. That's probably why it seems so confusing to most people.

But if you boil it down to a basic telephone circuit which connects between just two parties, things begin to clear up. You'll find that a complete basic telephone circuit has the following components:

1. A TRANSMITTER and RECEIVER at EACH of the two locations. The transmitter is the part of the phone which you use to transmit or send out your messages. The receiver is the part of the phone which is used to receive messages.
2. A means of SIGNALING. Unless the other party held the phone to his ear continuously, he'd never know when you wanted to talk to him.
3. A source of ELECTRICAL ENERGY. This is used to boost or push your messages over long stretches of wire.
4. A pair of WIRES connecting the phones.

And that's all there is to it. Of course, as a telephone lineman you'll refer to the telephone set as a SUBSET. The location of the subset is referred to as a SUBSTATION. And the wires connecting subsets are called the OUTSIDE PLANT.

HOW THE TELEPHONE WORKS

Now that you know what a basic telephone circuit is, suppose you find out how it works. To begin with, look at figure 288. It shows a wiring diagram of a basic telephone circuit. Now, the words "wiring diagram" shouldn't scare you. You've read *Use of Blueprints*, NavPers 10621, so you know that a wiring diagram is a short-cut method of representing an electrical circuit. Lines are used to indicate the wires of the circuit, and symbols represent the electrical devices connected to those wires.

Notice that all the parts of the basic telephone system are included in the diagram—that is, all the parts except one. That one item is the signaling bell. It hasn't been shown because its function is only to call attention to the fact that one party

wants to speak to the other. Thus, it plays no part in the explanation of how the telephone itself works.

Getting back to figure 288 you've probably noticed that the telephone circuit is of the SERIES type. You can prove this by tracing the electrons in their journey from the negative terminal *A* of the battery back to the positive terminal *B*. You'll find that the electrons follow just one path and pass through all the devices in the circuit.

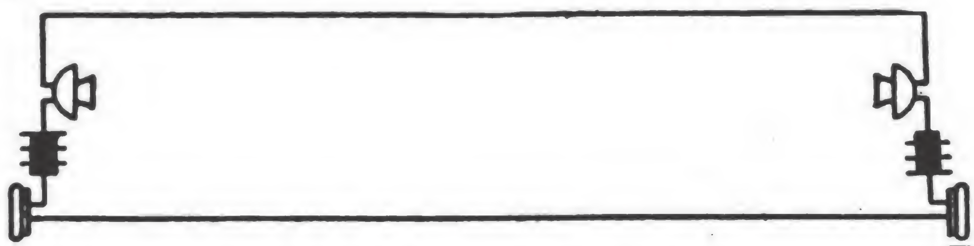


Figure 288.—A basic telephone circuit.

Figure 288 has given you some basic ideas on the telephone circuit. First, that the source of energy is a battery. Second, that this source provides a constant voltage. And third, that this voltage is used to operate the transmitter.

Of course, you could look at figure 288 all day and never discover HOW a telephone works. Some changes have to be made—like those in figure 289. First of all, only a transmitter at one location feeding into a receiver at the other end of the line is shown. Secondly, the transmitter and receiver have been sliced in half to show their internal working parts. And thirdly, the two batteries of figure 288 have been lumped together into one battery. This is possible, because the two batteries are in series with each other.

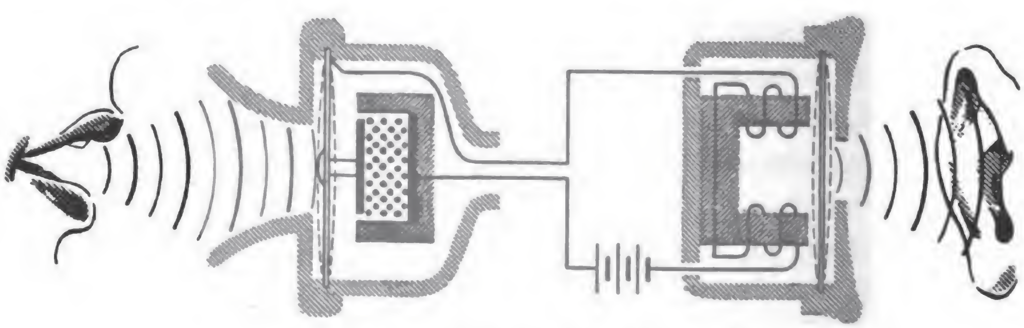


Figure 289.—How the telephone works.

Suppose you focus your attention on the transmitter construction. Here are its important features:

1. There is a chamber packed with small granules or grains of carbon.

2. The carbon granules are under pressure from a movable carbon disk which forms one end of the chamber.

3. The movable carbon disk is, in turn, directly attached to a flexible metallic diaphragm.

4. When the diaphragm is made to move forward, it pushes the carbon disk against the carbon granules, pressing them together.

5. When the diaphragm moves backward, it pulls the carbon disk away from the carbon granules, loosening them.

Next comes the receiver construction. Here are its important features:

1. A U-shaped permanent magnet.
2. A flexible metallic diaphragm that is slightly attracted to the pole pieces of the permanent magnet.
3. A pair of coils wound on the legs of the permanent magnet.

Now you're ready for the electrical circuit. To find out how it is set up, trace the electron flow. The electrons leave the negative terminal of the battery, travel through the coils of the magnet in the receiver and then over to the transmitter. At the transmitter, the electrons pass down the metal diaphragm, into the carbon disk, THROUGH the carbon granules, and then back to the battery.

You can see that if the battery voltage remains constant, the amount of electrons (current) which flows in the circuit will depend on the RESISTANCE of the circuit. If the RESISTANCE is HIGH, the electrons will have a hard time pushing through the circuit and the CURRENT will be LOW. If the RESISTANCE is LOW, the electrons will have an easy path and the CURRENT will be HIGH.

The electrons will meet resistance when passing through the carbon granules. How much resistance is offered depends on

how close the carbon granules are to each other. When they are tightly packed together, their resistance is low. When they are loosely packed, their resistance is high.

Now suppose you start to talk into the transmitter as shown in figure 289. You will set up sound waves (air disturbances) which hit against the transmitter diaphragm. The diaphragm will vibrate at the same rate as the sound waves. The carbon disk attached to the diaphragm will also move back and forth, alternately compressing and loosening the carbon granules. As the carbon granules change their position, the resistance they offer to the current will also change accordingly. Thus, a changing current flow is set up in the circuit. When this varying current passes through the coils of the receiver magnet, it will cause the magnet to increase and decrease in strength. These changes in magnetic strength produce, in turn, a varying attraction of the receiver diaphragm. As the receiver diaphragm moves back and forth, it sets up air disturbances or sound waves which are an exact copy of those you sent into the transmitter.

THE INDUCTION COIL

The wires which connect subset to subset have a definite amount of resistance. This resistance increases as the length of wire increases. As a result, when the phones are a normal distance apart, the wires offer enough opposition to the voice currents to affect the phone's operation.

This line resistance is the main reason why the basic telephone circuit in figure 288 has little practical use. To begin with, notice that the battery must send its energy completely around the circuit before it can energize the transmitter. So, if the line resistance is high, a very large battery voltage must be used to overcome it. Also, notice that the transmitter is connected directly to the line wires. This puts the resistance of the transmitter in competition with the line resistance. You'll remember that it's the changing transmitter resistance which produces the voice current. If the line resistance is high, in comparison to the changing transmitter resistance, then the voice currents produced will be weak.

The solution to the problem lies in separating the transmitter circuit from the line circuit. And yet you must still be able to transfer the voice currents from the transmitter over to the line. Now, what device do you know of that will meet these two conditions? The answer, of course, is the TRANSFORMER. From *Electricity*, NavPers 10622, you know that the transformer consists of a primary coil placed near a secondary coil. The two coils have no electrical connection with each other, the transfer of energy taking place through magnetic induction.

Figure 290 shows you how the transformer is placed in a telephone circuit. The primary coil is connected to the transmitter and battery. The secondary coil is connected to the receiver and line wires. Notice that the transmitter is electrically isolated from the line wires.

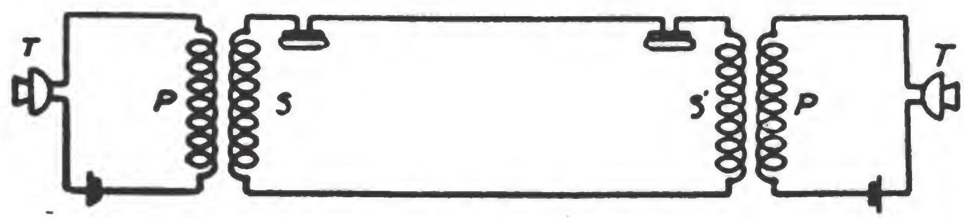


Figure 290.—Telephone system with induction coil.

Speaking into the transmitter on the left will cause a varying current to flow in the transmitter circuit. The varying current passing through the primary coils will produce an expanding and contracting magnetic field. This field will cut the turns of the secondary coil INDUCING a current in the secondary circuit exactly like the varying current in the primary circuit. The receiver of the subset at the other end of the line will pick up these voice currents and transform them into sound waves.

In most cases, the secondary coil will have more turns than the primary coil. This gives the added advantage of a step-up transformer which cuts down on the power losses. In telephone work, this transformer is referred to as an INDUCTION COIL. Most telephones have an additional winding included in the induction coil winding. This winding materially reduces voice (sidetone) reproduction in your own receiver. It is called the ANTISIDETONE winding or circuit.

AN IMPORTANT ADDITION

The battery used to energize the transmitter in figure 290 is usually of the dry-cell type with a 3- to 6-volt capacity. In chapter 3 of this book, you learned that a dry cell, once it has lost its power, cannot be recharged. All this sets you to thinking about the transmitter circuit in figure 290. You've been sharp enough to notice that once the battery is placed in the circuit it will continue to discharge, whether or not the phone is being used. And to your way of thinking, it means the unnecessary use of quite a large number of batteries.

The question of what can be done about it, is very easily answered. All that's required is a switch that will open the transmitter circuit when the phone is not in use. This switch could be hand-operated. In most cases, though, you'll find that the switch is automatically operated when the receiver or transmitter is picked up. The switch is termed a HOOK SWITCH.

The Hook Switch

Figure 291 shows you the type of hook switch used in a desk-stand subset. The hook or cradle part of the switch holds the receiver when the phone is not in use. When the receiver is removed from the cradle (figure 291), a hook spring forces two thin leaf springs together. Contact is made between the leaf springs by small contact buttons placed on the ends of the springs. The opposite ends of the springs are connected to the wires of the circuit.

A wiring diagram in figure 291 shows how the hook switch is connected to the circuit. Notice how closely the symbols resemble the actual working parts of the switch. One spring is connected to a common tie-point on the induction coil. The other spring is connected to the transmitter circuit. The hook spring is connected to the incoming line. Thus, the hook spring in the talking position puts both receiver and transmitter in operation. When the telephone is not in use, the hook spring moves away, breaking the receiver and transmitter circuit.

The different types of telephone sets make it necessary, of course, to use different styles of hook switches. But, the

purpose of the switch and its action are the same for all types of subsets.

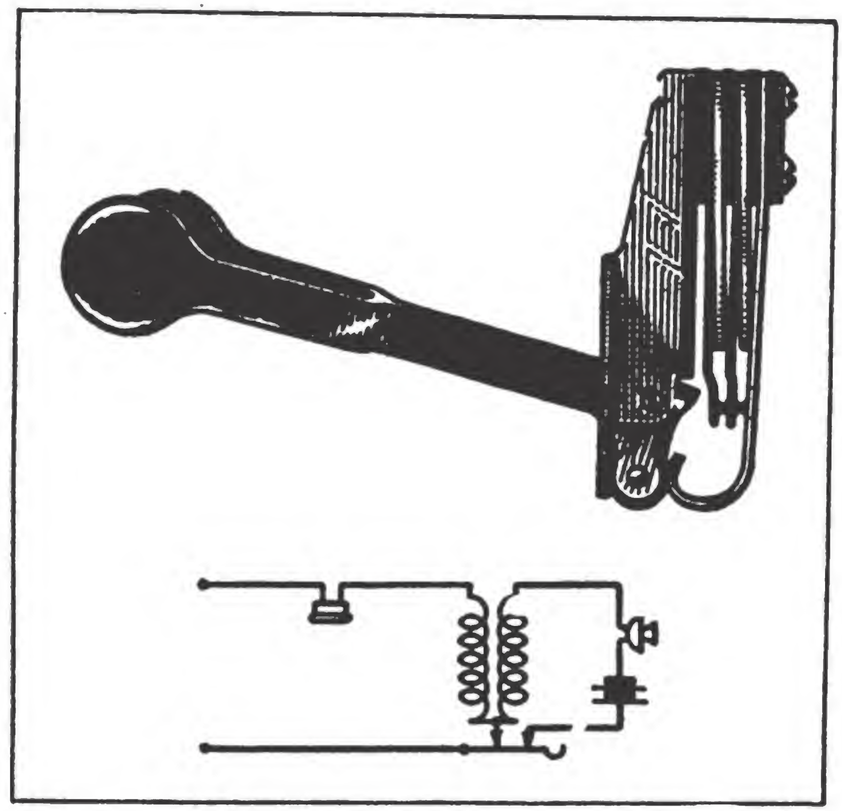


Figure 291.—The hook switch.

RINGING THE BELL

When the party on the other end of the line wishes to talk to you, he calls you to the phone by ringing a bell at your station. If you stop to give it much thought, you might wonder how a person, located, say 5 miles away, can cause that bell to ring.

What makes the bell ring is, of course, an easy question. It is electric current. How the electric current travels from the distant station to your station is also easy to answer. It is sent over the same wires which carry the voice currents between subsets. The big question, then, is where does the electric current come from? You'll score 4.0 if you answer a MAGNETO GENERATOR.

The Magneto Generator

The magneto used in telephone work is a small hand-operated a. c. generator. U-shaped permanent magnets fitted with pole pieces provide a strong magnetic field. An armature, supported by end bearings, is made to rotate in the field. A side-view of a magneto is shown in figure 292. In this case, four magnets are used to produce the magnetic field.

Notice the difference in size between the pinion gear attached to the armature shaft, and the large gear attached to the cranking handle. This gear ratio provides a means of turning the armature at a high rate of speed. At normal cranking speed, the output from the magneto is approximately 90 volts at 20 cycles.

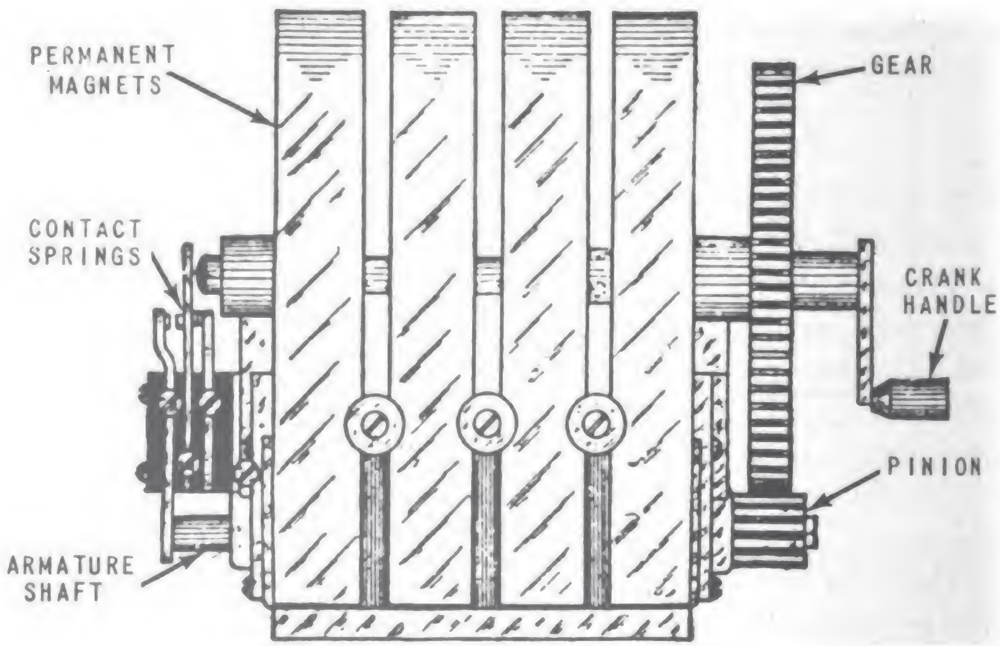


Figure 292.—The telephone magneto generator.

You've probably spotted the spring switch at the end of the generator. Its job is to connect the generator output onto the line, and, at the same time, remove the bell from across the line. This make-and-break contact is actuated by the crank-handle shaft. When you operate the magneto, the crank-handle shaft automatically moves forward, causing the switch to operate.

The Ringer

The current generated by the magneto energizes a bell similar to the one in figure 293. View *A* shows all the parts of the bell. M_1 and M_2 are ELECTROMAGNETS mounted on a soft iron yoke (Y). A TAPPER ROD (R) is rigidly attached to a pivoted iron ARMATURE BAR. The ends of the armature bar are directly over the ends of the electromagnets, but are separated by a small air gap. A PERMANENT MAGNET is placed with its north pole directly over the middle of the armature bar. Two GONGS (G_1 and G_2) are mounted so that the tapper rod will alternately strike each gong.

How the Ringer Works

View *B* of figure 293 shows a schematic diagram of the bell. It will help you to better understand the bell's operation. To begin with, notice that the north pole of the permanent magnet induces an opposite south pole in the middle of the armature bar. This action causes each end of the armature bar to assume a permanent north pole polarity.

Now, suppose the a. c. ringing current is sent into the coils of the electromagnet. Take the instant of time when the current is traveling through the coils in the direction shown in view *B*. The electromagnet M_1 will assume a north pole at its upper end while M_2 will have a south pole polarity. The end of the armature bar located over M_1 has a north polarity and will be attracted to the south pole of M_1. The other end of the armature bar also has a north polarity and will be repelled by the north pole of M_2. The result is a tilting of the armature to the right. Since the tapper rod is secured to the armature, it will move to the left and strike gong G_2.

On the next half-cycle, the current reverses direction, changing the polarity of the electromagnets. This causes the armature to pivot in the opposite direction, bringing the tapper rod against gong G_1. The tapper rod, then, will vibrate between the gongs as long as the ringing current is sent through the coils. This particular bell, by the way, is known as a POLARIZED RINGER.

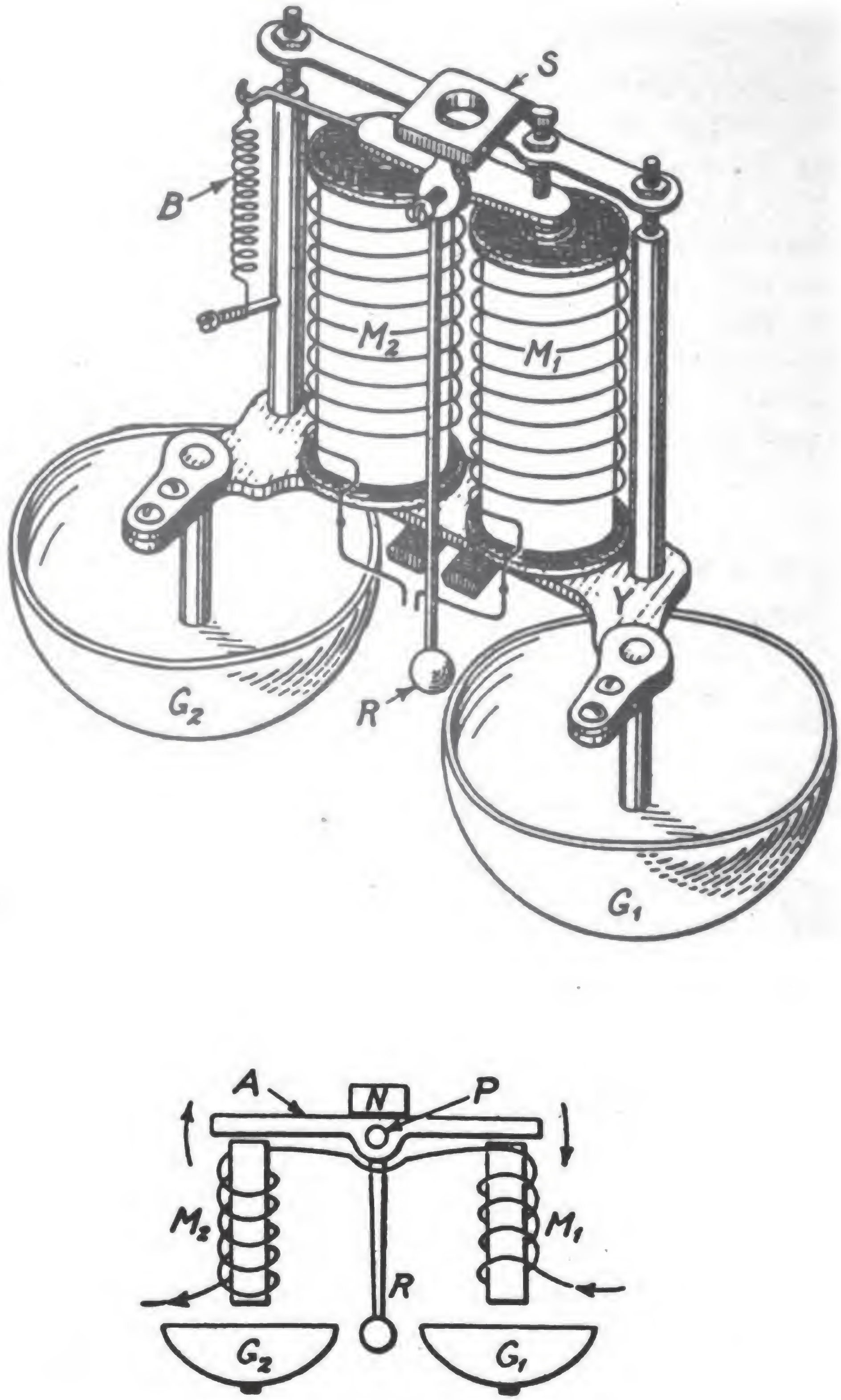


Figure 293.—The polarized ringer.

ADDING IT ALL UP

Transmitter, receiver, induction coil, battery, hook switch, ringer, and magneto generator—add them all together and you have a complete subset. Their connections in the telephone circuit is shown in figure 294. The position of the hook switch indicates that the phone is in the talking position. Notice how the magneto switch is utilized as a make-and-break circuit for the ringer and magneto circuits. When the magneto is not being cranked, the bells are across the line. Cranking the magneto causes the magneto switch to break the bell circuit and introduce the magneto output onto the line.

Although figure 294 indicates that the bells are across the line during normal conversation, they still will have no effect on the voice currents. Remember that the bells are designed to operate on approximately 20-cycle current. The voice-current frequencies are much higher. As a result, the bell presents a high impedance (a. c. resistance) to the voice currents, and they will continue on over to the receiver.

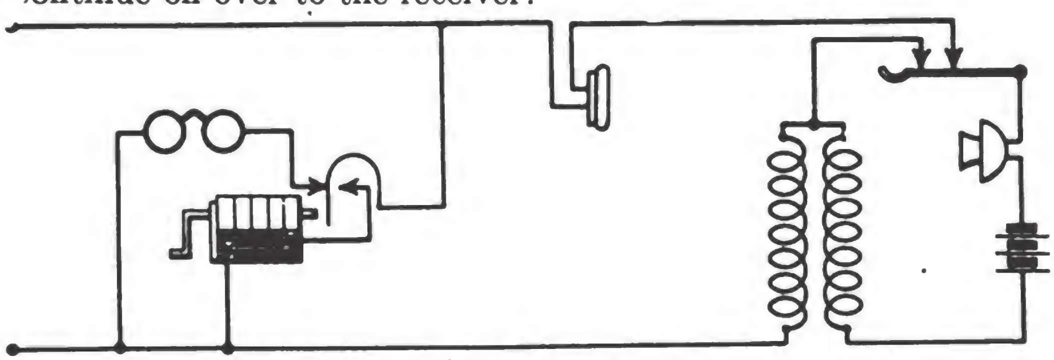


Figure 294.—Complete telephone circuit.

SNAFU

When two subsets are directly connected by a pair of wires, you have a simple two-substation system. But, start adding a few more substations, each desiring to be able to talk to one another, and things wind up in a SNAFU condition. The reason for all this is evident if you'll look at view *A* of figure 295. Looks complicated, doesn't it? Actually, however, all you have are six substations connected together so that any one station may talk to the other five. You can prove this by tracing the five circuits which leave each of the substations.

Obviously, there are plenty of disadvantages to the telephone system in view *A* of figure 295. To begin with, the large number of line circuits which are involved makes for a complex network. Secondly, it would be necessary to have five telephones at every station for each of the line circuits. Of, if you put all five line circuits on one phone, then the result is a loss of secrecy. Ringing one station will cause the other station phones to ring.

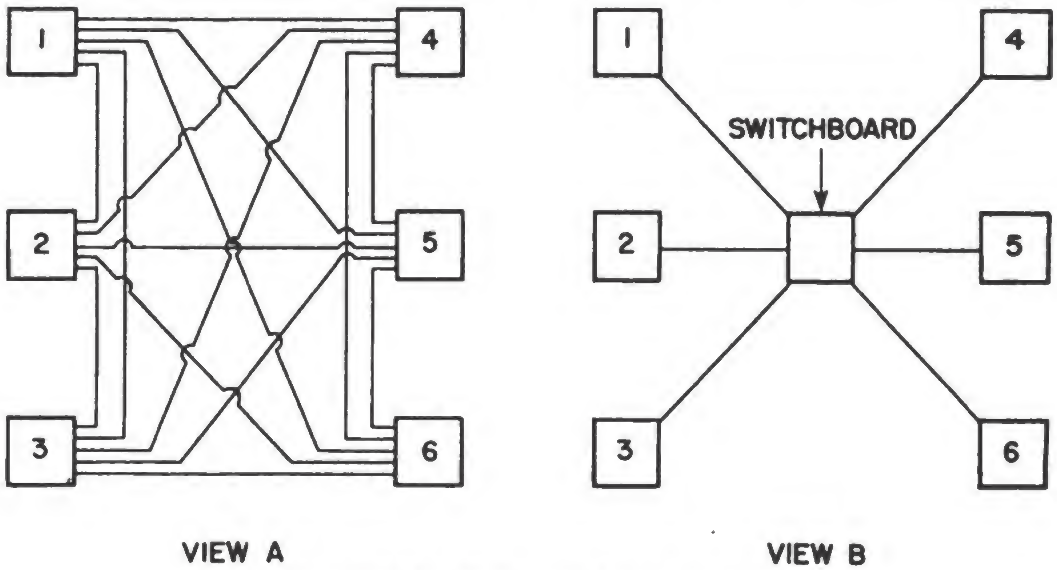


Figure 295.—Snafu vs. the switchboard.

To clear away the cobwebs, look at view *B* of figure 295. Instead of 15 line circuits, you have only six—one for each substation. But, notice that the line circuits are not directly connected. Instead, they enter an added piece of equipment labelled SWITCHBOARD.

THE BASIC SWITCHBOARD

A switchboard acts fundamentally as a switching point. To help understand its operation, take a look at figure 296. The basic switchboard shown, is the one serving the six substations in view *B* of figure 295. Notice that the switchboard consists essentially of a vertical panelboard and a horizontal shelf. Each pair of wires from each substation enters the back of the switchboard and terminates at a female plug receptacle (jack) mounted on the vertical panelboard. Associated with each jack

is a signaling device, which is usually mounted above the jack. On the horizontal shelf is a double row of male plugs. These plugs are the terminal points of cord circuits that hang beneath the horizontal shelf and are hidden from your view. There is a pair of plugs for each cord circuit. One plug of each plug pair is directly in front of the other. The plug nearest the panel is termed the ANSWERING plug. The plug nearest the front of the shelf is called the CALLING plug.

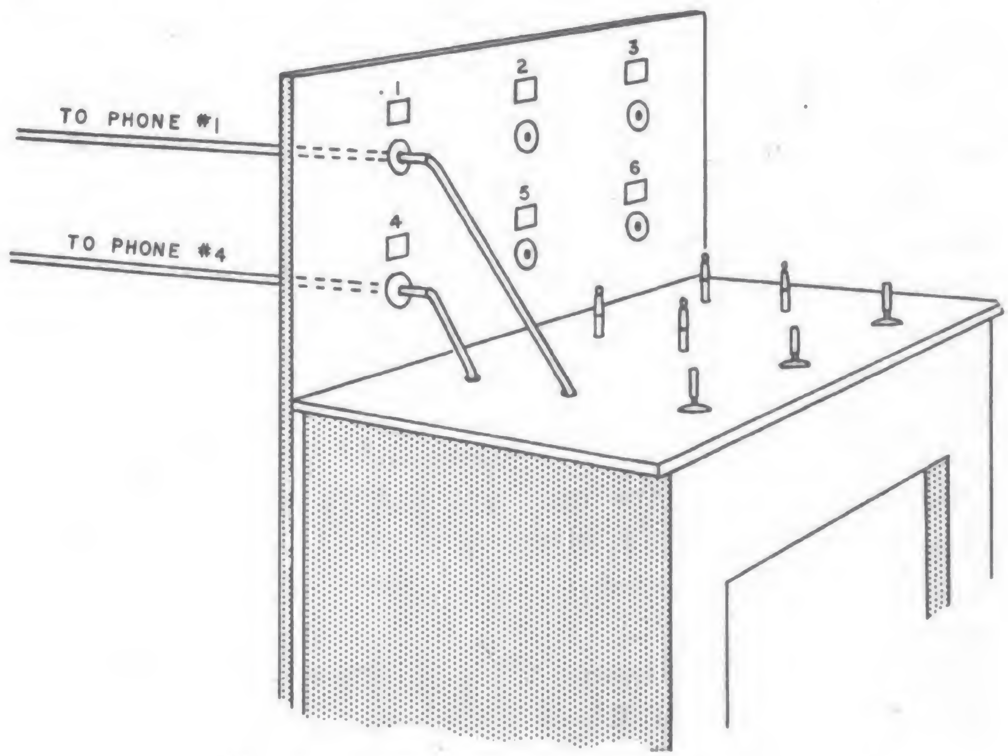


Figure 296.—Basic switchboard.

Each cord circuit is controlled by a three-way key switch. The lever arm of this switch can be seen directly in line with each pair of plugs. The switch is used by the switchboard operator to enable him to break into the cord circuit which connects two subsets. Thus, with the three positions of the switch, the operator can—

1. Insert his receiver and transmitter circuit into the cord circuit to talk to either party.
2. Insert his ringing circuit into the cord circuit to energize the signal bells at either substation.

3. Connect the two parties together for uninterrupted conversation.

OPERATING THE SWITCHBOARD

Take the case where substation #4 wants to talk to substation #1. The party at station 4 will crank his magneto generator, sending a 20-cycle ringing current over the wires to the #4 jack on the switchboard. Now suppose you are the operator at the switchboard. You will be sitting in front of the board, keeping an eye on the vertical panelboard. A receiver held to your ear by a headband, and a transmitter held near your mouth by a neckband, leave your hands free to work the plugs and switches.

When the 20-cycle ringing current arrives at jack 4 on the switchboard, it will cause the #4 signaling device to drop. When you see the drop operate, you select an idle cord circuit, pull the answering plug out from the shelf and insert it in the #4 jack (figure 296). Then you flip the cord circuit's associated key switch into the forward position. In this position, you are able to talk to station 4. Your query, of course, will be: "Number, please?" Station 4 will answer: "One." On hearing this, you reach over, pluck the calling plug out of the shelf and plug it into the jack labelled #1. You will then pull the key switch back as far as it will go. In this position, the switch is spring-operated and must be held there manually. This key switch position places the switchboard magneto generator across the line going to station 1. Thus, while you hold the key switch back, you can crank the switchboard magneto and send ringing current over to station 1.

When the bell at the subset in station 1 sounds off, the party at the station will pick up the phone. You can verify that he is on the line by placing the key switch in the forward or talking position. If station 1 answers, you flip the kep switch into its middle position. This allows station 4 and station 1 to carry on their conversation through the cord circuit.

When the call is completed, either one of the stations will signify this fact by ringing off. This involves sending a ringing current back to the switchboard. On some switchboards an

extra supervisory drop is installed for each cord circuit. This drop will operate on the ringing-off current. On other switchboards, you will have to rely on the regular signal drops to indicate when the conversation is finished.

A CLOSER LOOK

You can get a close-up shot of a switchboard jack and plug by looking at figure 297. You are also treated to a look at the symbols which represent the jack and plug in telephone wiring diagrams.

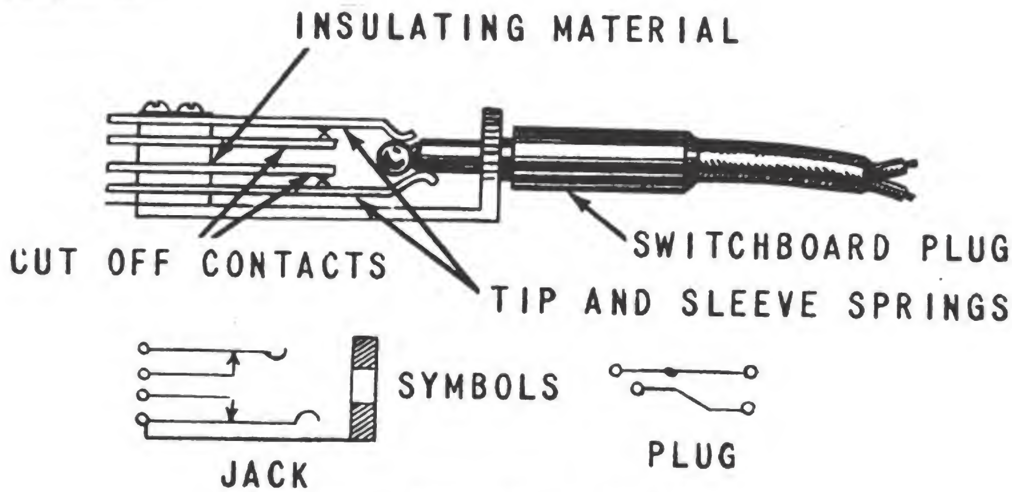


Figure 297.—Plug and jack.

When the plug is inserted in the jack, it makes contact with leaf springs. The tip of the plug hits against a TIP SPRING, while the metal sleeve bears against a SLEEVE SPRING. The two springs in the jack are connected to the incoming telephone wires. The tip and sleeve in the plug are connected to the wires in the cord circuit. Thus, you have a quick and easy way of transferring calls between stations on the switchboard. A tube made of hard insulating materials surrounds the back end of the plug. This is the part of the plug which you grasp when operating the switchboard.

THE SIGNAL DROP

You may have noticed those two short inner springs labelled cutoff contacts. The lower view of figure 297 shows these two springs in contact with the tip and sleeve spring—when the

plug is removed from the jack. This would indicate that inserting the plug breaks the contact between the springs and cutoff contacts, while removing the plug makes the contact.

The incoming telephone wires are connected to the tip and sleeve springs. Any energy coming over the wires will be routed onto the contact cutoffs when the plug is not in the jack. This is the condition which exists before the signaling current is sent to the switchboard. Thus, you would suspect that the cutoff contacts are connected to the signaling drop associated with that particular jack. A look at figure 298 will convince you that you're right. It shows how the 20-cycle ringing current causes the signaling drop to operate.

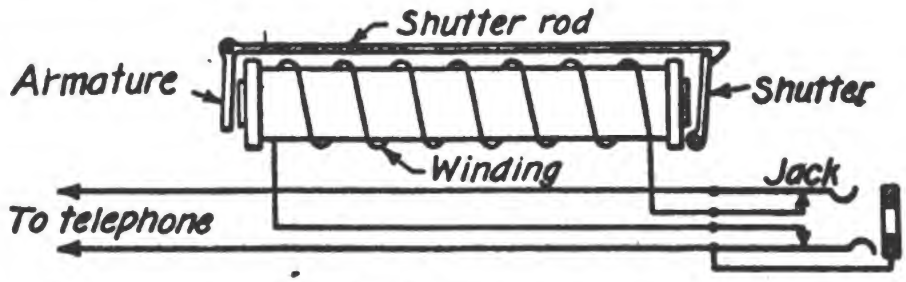


Figure 298.—Signal-drop.

As you can see, the ringing current comes over the telephone lines to the jack at the switchboard. Then, it travels through the cutoff contacts into an electromagnet. When the ringing current energizes the electromagnet, two things take place. One, the armature is attracted to the electromagnet, causing the pivoted shutter rod to lift away from the shutter. Two, the pivoted shutter will fall forward, indicating an incoming call. The shutter is replaced in its normal position by the operator. Or, if it is of the self-restoring type, the insertion of the answering plug in the jack will force the shutter up into its normal position.

THE SWITCH KEY

You know how to operate the switch key on the switchboard. And you know, generally, what the three positions of the key do in the cord circuit. But, you probably don't know exactly how the key works. Figure 299 will help you in this respect.

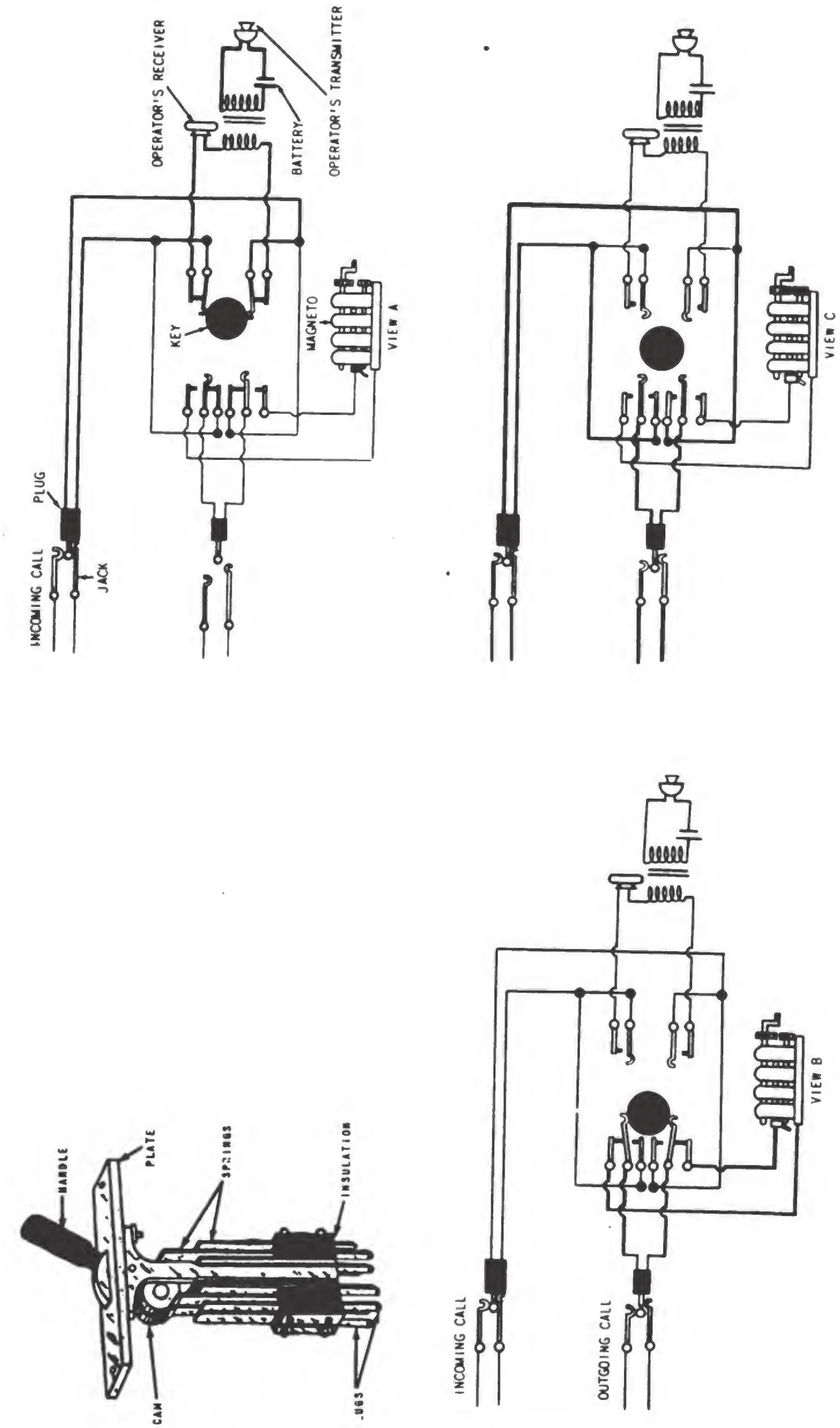


Figure 299.—The cord circuit.

It shows you the construction of the key, plus three views of the cord circuit corresponding to the key's three positions.

The construction view of the key reveals that it is simply another make-and-break spring switch. The movement of the key handle causes a cam to press against the springs of the switch, opening and closing the contacts in the cord circuit. In the picture, the key handle has been moved into the forward position. The cam is now operating against the springs which control the switchboard operator's talking circuit.

Now look at view *A* of figure 299. It shows the complete cord circuit in a schematic diagram. The answering plug has been inserted in the jack in response to an incoming call. The operator has pushed the key forward into the TALKING position. If you follow the heavy lines, you'll find that this action places the operator's subset across the cord circuit.

Next, in view *B*, the calling plug has been inserted in the jack of the number being called. The key has been pulled back into the RINGING position. You'll notice that this places the operator's magneto across the cord circuit leading to the calling plug. Turning the magneto sends ringing current to the party called.

Follow the heavy circuit lines of view *C*, and you'll discover that there's a clear path from the answering plug to the calling plug. This happens when the key is in its MIDDLE or NEUTRAL position. The calling party now has a complete connection with the called party.

LOCAL- AND COMMON-BATTERY SYSTEMS

From the time you started this chapter up until this point, you were reading about just one type of telephone system. It is called a LOCAL-BATTERY SYSTEM. Now, you're going to be introduced to another type of telephone circuit—the COMMON-BATTERY SYSTEM.

Learning what makes a common-battery system tick is going to be easy. That's because the common-battery system is so much like the local-battery system. The main difference between the two systems lies only in the location of the energy source that operates the phones.

A quick review of the local-battery system will prove helpful. Here, briefly, is the story:

1. There is a battery at EACH subset substation. This battery provides the direct current necessary for the operation of the subset's transmitter.

2. The transmitter and battery circuit of each subset is separated from the line circuit by a transformer (induction coil). Thus, in a local-battery system, there is NEVER a direct current flowing in the wires which connect subset to switchboard. Only alternating current, either voice or ringing, flows over these wires.

Now for the common-battery system.

The main changes are these:

1. There are no batteries at the subsets serving in the system.

2. The direct-current energy for the subset's transmitters is supplied from a battery LOCATED AT THE SWITCHBOARD.

3. The wires connecting subset to switchboard carry not only the ringing and voice currents (a. c.) but also the battery current (d. c.) from the switchboard.

QUESTIONS ON THE SUBSET

Naturally, some questions arise in your mind concerning the common-battery system. Probably, the biggest thing that puzzles you is how the direct current is transferred from the power source at the switchboard to the transmitter at the subset. After all, the subset circuit you are familiar with (figure 290) has the transmitter separated from the line by a transformer. And you know that direct current will not pass through a transformer. Well, the logical answer, of course, is that this type of subset will not work in a common-battery system. Some change will have to be made—similar to that in the basic common-battery subset circuit of figure 300.

You'll notice that the change is a simple one. It consists of reversing the positions of the transmitter and receiver in the circuit. Now the receiver is across the secondary of the transformer. It is ready to receive, through the transformer, any

voice currents which come over the line. The transmitter has been placed in the receiver's former spot—in series with the primary of the transformer. Thus, the transmitter is in a position to receive the direct-current energy sent from the switchboard office.

Another question which you want answered, is why a capacitor is placed in the bell circuit. The capacitor is used to prevent the bell from being energized by the direct current which is always flowing in the line wires. Capacitors, you know, stop direct current. How does the bell ring? That's easy. The ringing current is an alternating current and capacitors allow alternating current to pass through.

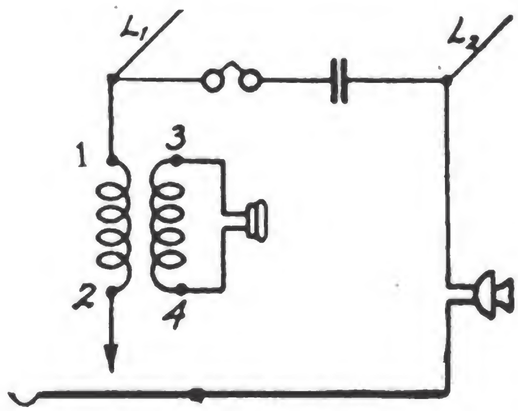


Figure 300.—Common-battery subset.

QUESTIONS ON THE SWITCHBOARD

No doubt you also have some questions on the common-battery switchboard. For example, you know that in the local-battery system, ringing current is sent out from the subset. But, since the common battery has no magneto, you are probably wondering how the switchboard operator is signalled. Actually, it is the direct current sent out from the switchboard office that does the work. When the receiver is lifted from the hook switch, the circuit is completed between the subset and the switchboard. The direct current which flows in this completed path energizes a circuit at the switchboard which, in turn, causes a small signal lamp to burn. In other words, as an operator at a common-battery switchboard, you will see signal

lamps associated with jacks instead of signal drops. You will also find supervisory lamps instead of supervisory drops, to tell you when a call is completed.

Another question you might have is, how does the switchboard operator send out ringing current? You'll find that the key is pulled back into the normal position for ringing, but it isn't necessary to turn a magneto. RINGING MACHINES are provided at common-battery switchboards for this purpose. These ringing machines usually operate from a local power supply of 115 volts and 60 cycles. They produce a ringing current of approximately 90 volts at 20 cycles. The "telering" and the "subcycle" converter are two such ringing machines.

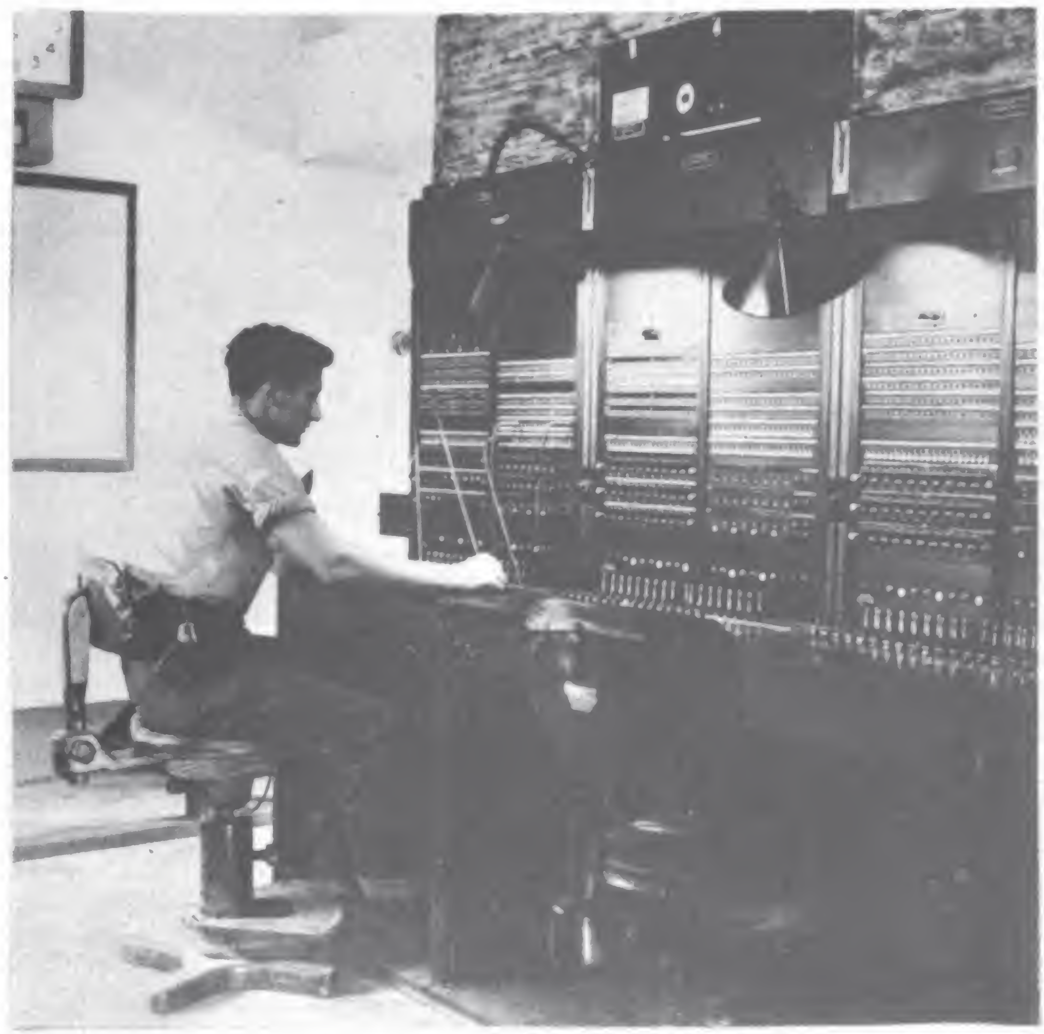


Figure 301.—PBX switchboard.

PBX SWITCHBOARDS

A small area or building may contain enough phones to warrant the use of a PBX SWITCHBOARD. The letters PBX stand for PRIVATE BRANCH EXCHANGE. From the PBX switchboard, trunk lines are run to the larger exchange switchboards.

A typical PBX switchboard office is shown in figure 301. It is actually made up of three separate switchboard units. Notice that both lamp and signal drops are used. This indicates that the switchboards serve both local- and common-battery phones.

DISTRIBUTING FRAMES

The function of a switchboard is to act as a central switching point for a large number of phones. Thus, you can expect many incoming lines to enter the switchboard office. These lines, however, do not go directly to the switchboard jacks. Instead, they are sent over and permanently terminated on DISTRIBUTING FRAMES. Lines from the switchboard jacks are also brought over to the distributing frame. Jumper wires interconnect the outside wires to the proper inside wires. One distributing frame in a switchboard office is called an MDF or MAIN DISTRIBUTING FRAME. An additional frame is termed an IDF or INTERMEDIATE DISTRIBUTING FRAME.

The reasons for using a distributing frame can easily be listed:

1. It provides a point where the incoming wires and the switchboard wires may be permanently terminated in an orderly fashion.
2. It provides an easy means of interchanging connections between the switchboard wires and the incoming wires.
3. It provides a convenient spot from which tests may be made.
4. It provides a place for mounting protective devices.

A typical distributing frame is shown in figure 302. In this case, it is serving a common-battery switchboard which is to the left and beyond the picture. Notice the incoming lines at the

upper right-hand corner of the distributing frame. Check the four reasons listed above against the illustration and you can easily see why it is necessary to use a distributing frame.

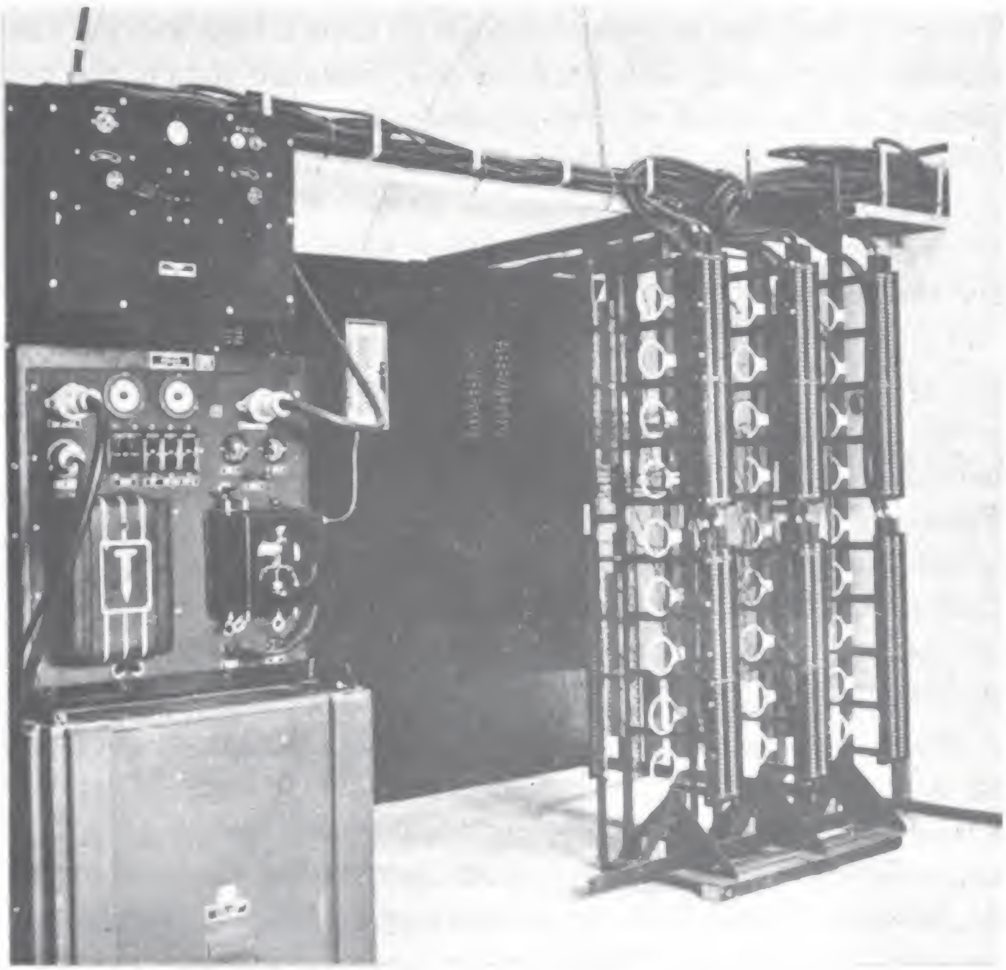


Figure 302.—A typical distributing frame.

PROTECTIVE DEVICES

The telephone lines of the outside plant do not normally carry high voltages or high current. And yet, you will find that protective devices are necessary to safeguard both personnel and telephone equipment. That's because the telephone wires, when run overhead, are exposed to electrical hazards. Lightning is one example, and accidental contact with power lines is another.

The three types of protective devices which you will encounter are HEAT COILS, FUSES, and LIGHTNING ARRESTERS. These devices are placed in the lines, both at the substation and the switchboard office.

HEAT COILS are used as protection against "sneak" currents. These currents are not great enough to blow a fuse and yet can damage equipment. The heat coil is so designed that prolonged passage of the sneak current causes a fuse link to melt. This action releases a spring which contacts ground. The spring is in series with the incoming telephone wires. Thus the sneak currents are routed to ground before they have a chance to damage the telephone equipment.

The heat coil doesn't open the circuit, but merely bypasses excessive current to ground. If that current becomes too large, it will damage the wires of the outside plant. Thus, it will be necessary to insert FUSES in series with the incoming wires. Fuses are nothing more than links made of a low-melting point alloy. They are purposely made weaker than the wires which they protect. As a result, the fuse link will melt and open the line before the wires can be damaged. Tubular shells, about 4 inches long, protect the fuse link from mechanical abuse.

When lightning strikes exposed telephone wires it produces an excessive surge of voltage. Unless this energy is quickly drained away to ground, it might cause damage to personnel and equipment. LIGHTNING ARRESTERS are the "valves" which do the job. They consist essentially of two carbon blocks separated by an air gap. One block is connected to the line wire, the other is tied to ground. When the high lightning voltage appears on the line, it will break down the air gap between the carbon blocks. Excessive energy can then follow an easy path to ground. When the high voltage disappears, the arc is snuffed out and the line returns to normal.

Telephone lightning arresters are constructed so that a permanent ground is developed in case the high voltage lasts a long time. One of the carbon blocks is imbedded in a porcelain container and held in place by glass cement. When the arc lasts for an appreciable time it will melt the glass cement releas-

ing the carbon block. Pressure exerted by a spring forces the block against the grounded carbon block of the arrester.

DIAL TELEPHONE SYSTEMS

A switchboard operator has to be on his toes at all times. Handling the cord circuits on just an ordinary size switchboard, calls for an efficient, experienced man. But like all other humans he's bound to make mistakes. That's why someone invented a device to replace the operator. This device is called an AUTOMATIC SWITCHBOARD.

Automatic switchboards are rather complex because of the added equipment necessary to perform their function. This is especially true of the larger switchboards which serve thousands of phones. So your best bet, if you're going to learn the principles of a dial system, is to concentrate on the simplest automatic switchboard exchange. This is one which serves a system of 100 phones or less.

The Connector Banks

In a 100-phone system, a pair of wires from each phone is brought over and terminated in the switchboard central office. Normally, if this were a manual switchboard, each pair of wires would terminate at a jack on the board. But, since there will be no operator at the board to complete connections between the jacks, something new must be added. The new addition is called a CONNECTOR BANK. It is part of the device which automatically makes the connections between subsets. The 100 pairs of wires will terminate at the connector bank.

The connector bank will consist of 100 contacts. These contacts are arranged 10 to a row, 10 rows high. A picture might help just about this time, so look at figure 303. It shows the schematic diagram of three connector banks for a 100-line system.

Three phones, #14, #87, and #95 are shown tied into the connector banks. Take the #14 phone first. Follow the line out of the phone until you reach the tap wire at point *A*. Trace the wire down and you find it connects to a contact on the first connector bank. Tap wires at points *B* and *C* also connect

phone 14 to contacts in the second and third connector banks. Notice that the contacts for phone 14 occupy the same relative position in all three connector banks.

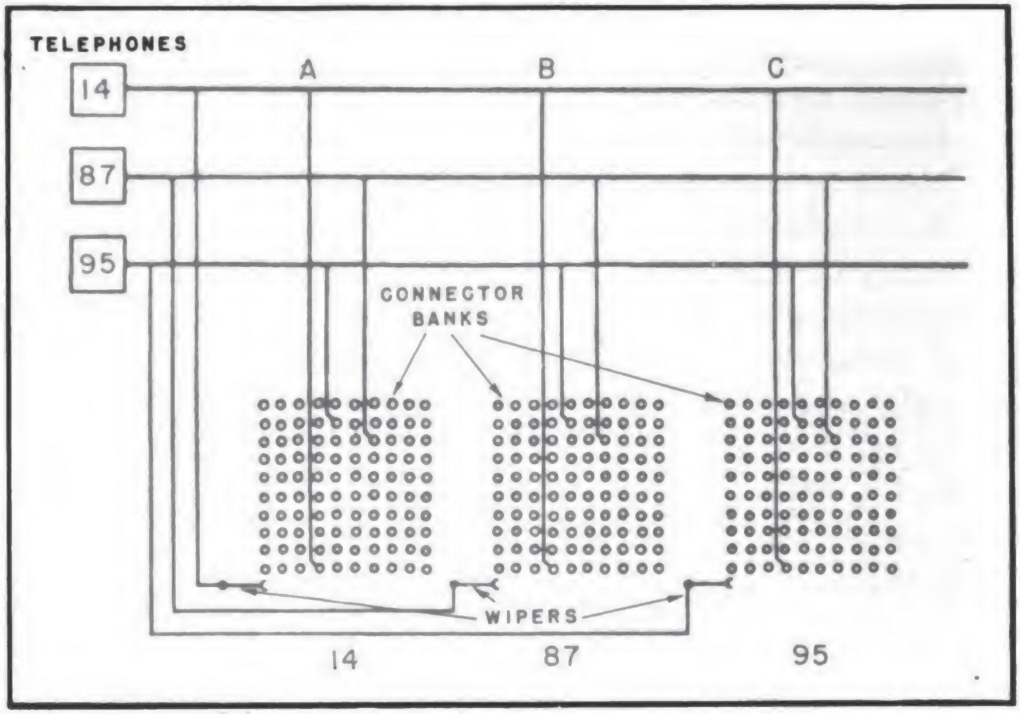


Figure 303.—100-line system diagram.

A Definite System

The contact for phone 14 wasn't just chosen at random. It follows a definite system of planning. For example, notice that the contact is on the FIRST LEVEL of the bank. This corresponds to the number "1," which is the first digit in #14. Also notice that the contact is FOUR VERTICAL ROWS over to the right. This corresponds to the number "4," which is the second digit in #14. Thus, you can set down two rules for the location of the contact for a phone.

1. The first digit of the phone's number will indicate the level in the connector bank.

2. The second digit will indicate the vertical row from left to right.

To make sure you're correct on this, try applying it to phones 87 and 95. Phone 87's contact should be on the EIGHTH level and SEVEN vertical rows over. Phone 95's contact should be on

the NINTH level and FIVE rows over. Check it with figure 303 and you'll find that you're right on the beam.

The Connector Switch

You've probably noticed that each phone of figure 303 is connected to a WIPER. This wiper is part of a device called the CONNECTOR SWITCH. It performs the mechanical motions necessary to make the connections between subsets.

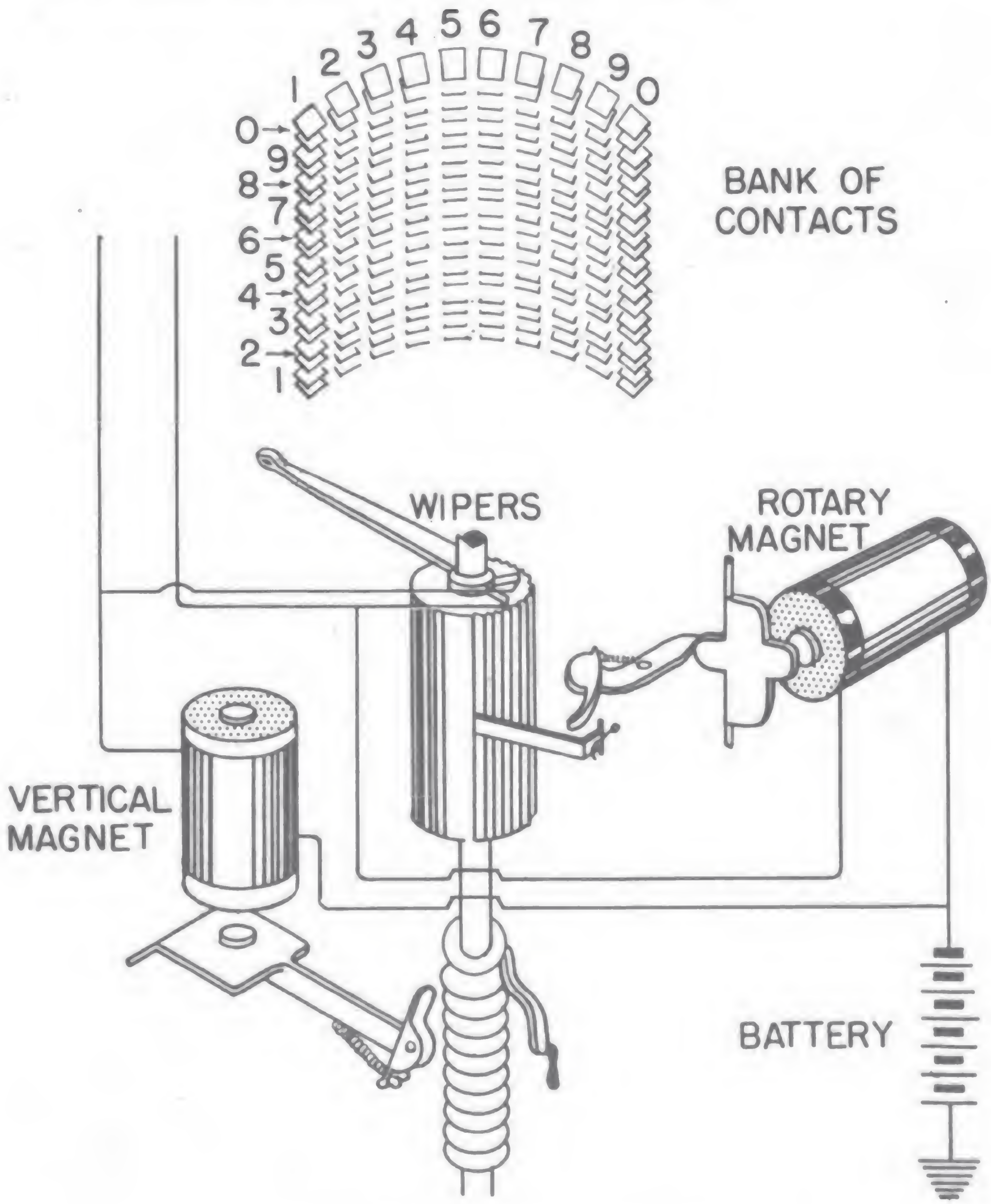


Figure 304.—A connector switch.

The brushes or wipers are rigidly mounted on a shaft which is placed in front of the connector bank. The shaft can be made to move in a step-by-step rotary motion and a step-by-step vertical motion. Thus the wipers can be directed and placed on any one of the 100 contacts in the connector bank. Electromagnetic devices, actuated by impulses, provide the lifting and rotating power necessary to move the shaft.

A simple drawing of a connector switch is shown in figure 304. You can see very clearly how the ratchet and pawl assemblies impart a step-by-step rotary and vertical motion to the connector-switch shaft.

The Dial Phone

Where do the impulses come from that operate the connector switch? You'll find that they are sent over from the subset which is making the call. In other words, the automatic switchboard's actions are controlled by the calling party.

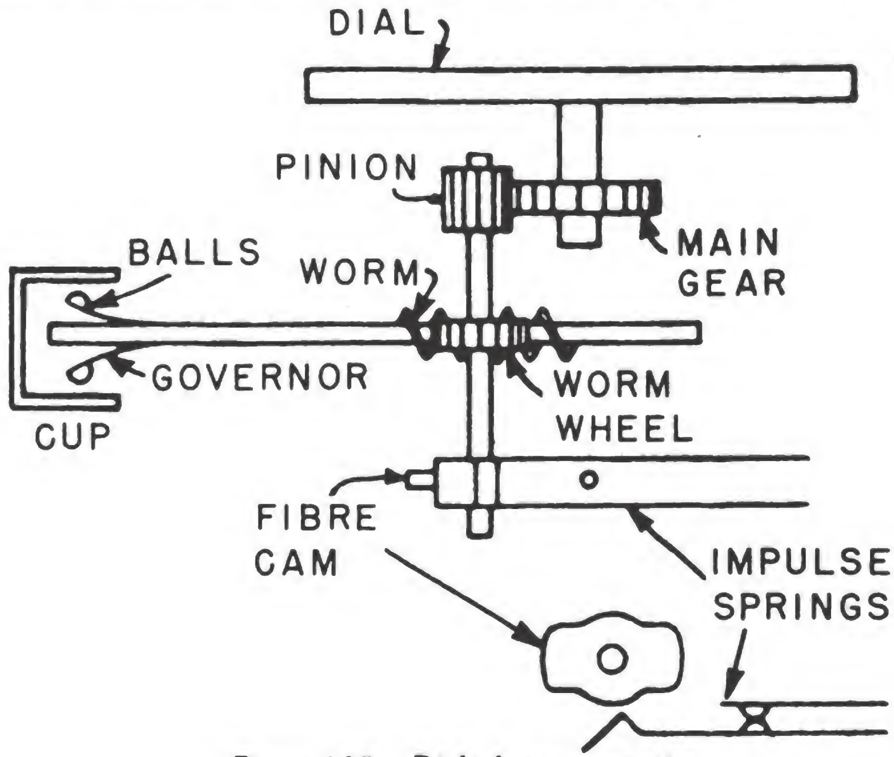


Figure 305.—Dial-phone mechanism.

The impulses are produced by a dial mechanism mounted in the base of the subset. All that the person using the phone sees is a dial plate with finger holes spaced around the outside edge.

When the dial plate is in its normal position, each finger hole is identified by a number which can be seen through the hole. A finger stop permits you to turn the dial plate just so far.

Now, suppose you take the phone apart. You'll find a dial mechanism similar to the one in figure 305. Notice that the dial plate is gear-connected to a fiber cam. Turning the dial plate causes the fiber cam to rotate. Each time the cam completes one-half revolution, it opens the contacts of an IMPULSE SPRING. The impulse spring is connected to the incoming wires which carry direct current from the automatic switchboard. And every time the cam kicks open this circuit, it produces an impulse in the line. It's these impulses which operate the lifting and turning mechanism of the connector switch. The governor assembly in figure 305 maintains a constant speed of the cam revolutions. This is to prevent a pile-up of impulses at the connector switch. The governor is usually set to insure an output of 10 impulses per second.

COMPLETING THE CALL

What are the train of events that take place when a call is made? Focus your attention on figure 303 to find out. Suppose that substation 14 wanted to call substation 87. When the receiver is lifted it completes a direct-current path between subset 14 and the automatic switchboard. This action causes a LINE SWITCH to connect subset 14 to the wiper of a connector switch serving an idle connector bank. In this case (figure 303), subset 14 is connected to the wiper of the first connector bank.

Now, the person at subset 14 will place his finger in the dial-plate hole numbered EIGHT. He will rotate the dial until his finger comes against the finger stop. When he releases the dial it will return to its normal position. In doing so, it operates the cam so that the impulse circuit is opened EIGHT TIMES. These eight impulses are sent over to the connector switch. They cause the vertical electromagnet to move the shaft up EIGHT STEPS. This places the wiper on the eighth level of the connector bank.

Next, the number SEVEN is dialed. Seven impulses are sent over to the horizontal magnet. Each impulse moves the connector switch SEVEN STEPS to the right. This places the wiper on the contact in the SEVENTH VERTICAL ROW. If you'll follow the wires from this contact, you'll find they connect to subset 87. Thus the call is completed.

SUMMARY

Sound travels through the air in the form of waves or air disturbances.

The transmitter changes these air waves into current fluctuations.

Passing this current through an electromagnet causes the magnet's intensity to fluctuate. This fluctuation, in turn, vibrates a diaphragm. The diaphragm creates sound waves. Thus, the receiver changes fluctuating current into sound.

A basic telephone circuit consists of two subsets connected together by means of two wires. Each subset is composed of a transmitter, a receiver, a bell, an induction coil, and a source of energy.

The induction coil is used as a booster in the local-battery subset.

The hook switch is simply used to open or close the transmitter circuit.

The magneto generator is used as a ringing source. It generates approximately 90 volts, at 20 cycles.

A switchboard permits the use of a minimum of wires with a maximum of efficiency and privacy.

As a switchboard operator, you must know how to:

1. Connect the lines to your headset.
2. Connect the two parties together, and when to disconnect them.
3. Ring the subsets.
4. Determine when a party is trying to contact you.
5. Maintain your equipment in top mechanical condition.

The protective devices of the telephone system consist of heat coils, fuses, and lightning arresters.

A connector switch is the "switchboard operator" of the dial system.

Impulses (breaks in the current) are sent over the line according to the number you dial. They are made as the dial returns to its normal position.

A wiper rises one notch for each impulse received. It then rotates one notch for each impulse sent out when you dial the second number.

Each connector switch contains 100 contacts. The number of connector switches determines how many parties may make calls at the same time.

Exchanges serving more than 100 subsets must have additional connector switches to take care of the additional numbers dialed.

QUIZ

1. Name the five parts of the basic telephone circuit.
2. Does compression of the carbon granules in the transmitter increase or decrease the resistance?
3. Name the three essential parts of a receiver.
4. What is another name for an induction coil?
5. What is the purpose of the induction coil in a telephone circuit?
6. Does the telephone switch open or close the local battery circuit when the receiver is removed from the instrument?
7. What is the normal voltage and cycle output of the telephone magneto generator?
8. Does the ringer use direct or alternating current?
9. What device is inserted into the switchboard jack?
10. The three-way switch on the switchboard performs what three functions?
11. Are the batteries in a local-battery telephone in series or parallel with the transmitter?
12. What kind of current always flows in the wires of the outside plant in a local-battery circuit?
13. Where are the batteries located in the common-battery circuit?
14. What is the purpose of the capacitor in the common-battery subset?
15. What is a small private switchboard called which only serves a single building or small area?
16. Where are the incoming lines terminated on large switchboard installations?
17. Name three types of protective devices found on telephone equipment.
18. What is meant by the term "impulses" when speaking of automatic equipment?

CHAPTER 13

TELEPHONE-LINE CONSTRUCTION

BEFORE

Establishing telephone communications in double quick time is important during a battle. You can't wait for telephone poles to be set up. It becomes strictly a matter of stringing the wires between subsets in the most direct way possible. That means draping the wire over bushes and trees, or just laying it on the ground. And, if a stream gets in the way, running the wire right through it.

Naturally, this kind of rough treatment calls for a wire that can take it. The wire is termed FIELD WIRE. It is a twisted pair, rubber insulated, with an outside braid covering. The conductors are composed of both steel and copper strands—the steel for strength, the copper for conductivity.

AFTER

Once the base has been established, the communications system is set for an overhaul. The field wire should be replaced

with regular telephone wire or cable. And what is most important, the wire or cable should be set in a safe spot. It may either be strung overhead or placed underground.

POLE-LINE CONSTRUCTION

Remember when you read chapter 9 of this manual? It covered the construction phases of power-line work. As a telephone lineman you've probably wondered all along why you had to study it. That's easy enough to answer. You see, this chapter—chapter 13— covers the stringing of telephone wire and cable. And when telephone wire or cable is strung overhead, wooden poles are used as supports. Naturally, you'll be expected to erect the poles before you string the cable or wire. Which shouldn't be hard for you, because you've already studied pole-line construction. It was all there in chapter 9—digging holes, raising poles, climbing, attaching crossarms, and guying.

STRINGING OPEN WIRE

The telephone lines which compose the OUTSIDE PLANT may be strung in two forms. They can be either separate open wires or wires combined into a lead-sheathed cable. Each requires a different method of mounting on the telephone pole.

In stringing open wire, you will be required to mount a number of bare copper conductors on crossarms. Each conductor is kept in place by tying it to an insulator. You'll find that the operation of stringing telephone wire is very similar to stringing wires for power lines. In fact, the main difference between the two is the number of wires involved. Since, basically, each telephone circuit requires two wires, there will be more wires strung for telephone than for power work. But the main operations involved are the same:

1. Reeling out the wires.
2. Raising the wires to the crossarms.
3. Tensioning the wires.
4. Tying the wires in.

The four basic operations outlined above are covered in the first half of chapter 10 of this manual.

TELEPHONE CABLE

You probably have seen about 20 or 30 open-wire telephone conductors strung along a stretch of poles. And maybe running right below it a single cable about 1½ inches in diamter. It may surprise you to find out that there are more telephone wires inside that cable than on the crossarms above. In fact, some telephone cables carry as many as 2,121 pairs of wires.

The question which might arise in your mind is how so many wires can be contained in a cable no bigger than your fist. Well, first of all, telephone wires carry only small amounts of currents. Thus, the size of the wires can be very small. Secondly, the voltages are not high, which means the insulation may be thin. In most cases a single wrap of dry paper is all that's necessary for each wire. Then by twisting the wires in a spiral and covering them with a lead sheath a compact cable is made. The lead sheath acts as a waterproof covering plus a shield against outside magnetic disturbances.

Naturally there are disadvantages to telephone cable. Just let a small amount of moisture enter the cable and it becomes useless. The wires are so closely packed together and their insulation so thin that moisture produces almost a dead short. Thus, great care in splicing and handling the cable is necessary.

THE SUSPENSION STRAND

Telephone cable can't be strung on poles like open wires. It requires more than just a support point at each pole. So before you string the cable you must first place a SUSPENSION STRAND on the poles along the cable right-of-way. The suspension strand or MESSENGER is made of galvanized steel wire and acts as a support for the cable along its entire length.

Placing the Suspension Clamp

The first step in stringing the messenger is to provide it with supports at each pole. These supports consist of a CABLE SUS-

PENSION BOLT and a CABLE SUSPENSION CLAMP. The suspension bolt comes in two types—*A* and *B*. The *A*-bolt has a square head on one end and threads on the other, while the *B*-bolt is threaded on both ends. The *B*-bolt is used where cable is run on each side of the pole.

Figure 306 shows you the typical installation of an *A*-bolt and suspension clamp. A hole is first bored through the pole. Then the *A*-bolt is driven through the hole and a nut screwed on. Before tightening the nut, be sure you have placed a square

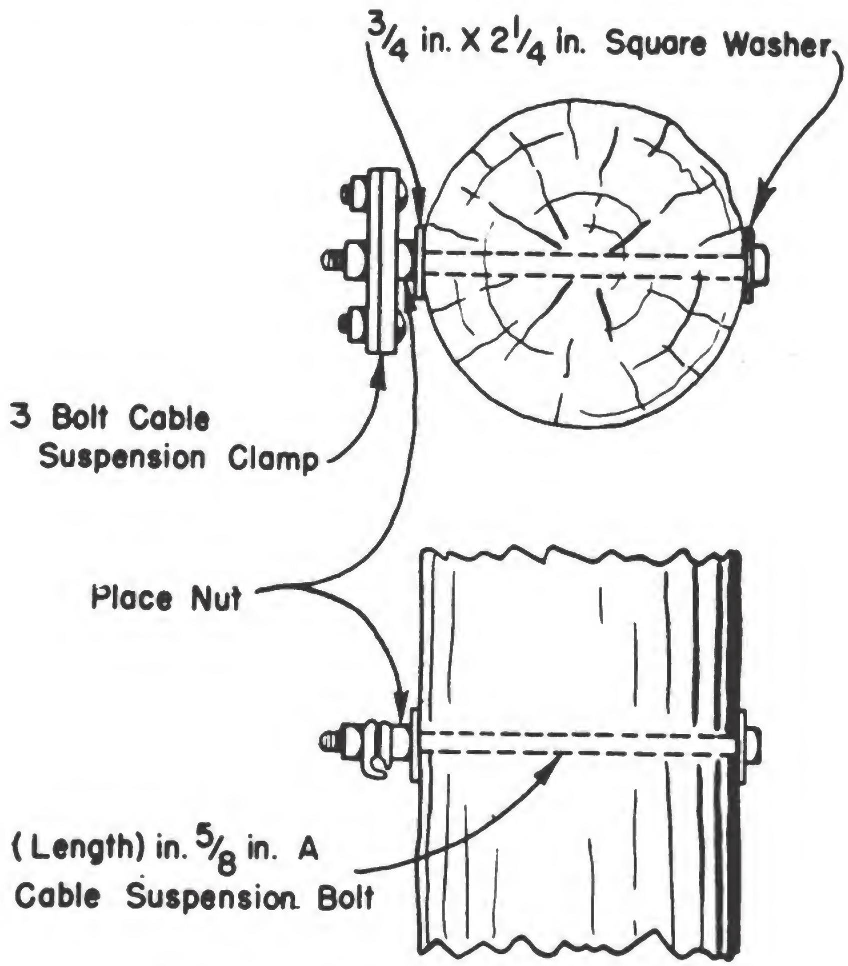


Figure 306.—Suspension-clamp installation.

washer under the head of the bolt and under the nut. The suspension clamp is then placed on the threaded end of the *A*-bolt.

While you're at it, take a look at the construction of the suspension clamp. It consists of two long metal bars that may be

clamped together by tightening a bolt and nut assembly. One of the bars has an overhanging lip which forms a groove. It is this groove which holds the suspension strand or messenger.

Stringing the Messenger

With the suspension clamps in place you are ready to string the suspension strand. Where ground conditions permit, the strand may be unreeled on the ground alongside the poles. As each pole is reached, the strand is carried up the pole and placed in the suspension-clamp groove. The clamp nuts are tightened just enough to keep the strand from falling out.

The suspension strand must then be pulled to the proper tension or sag. This involves the use of a strand puller and block

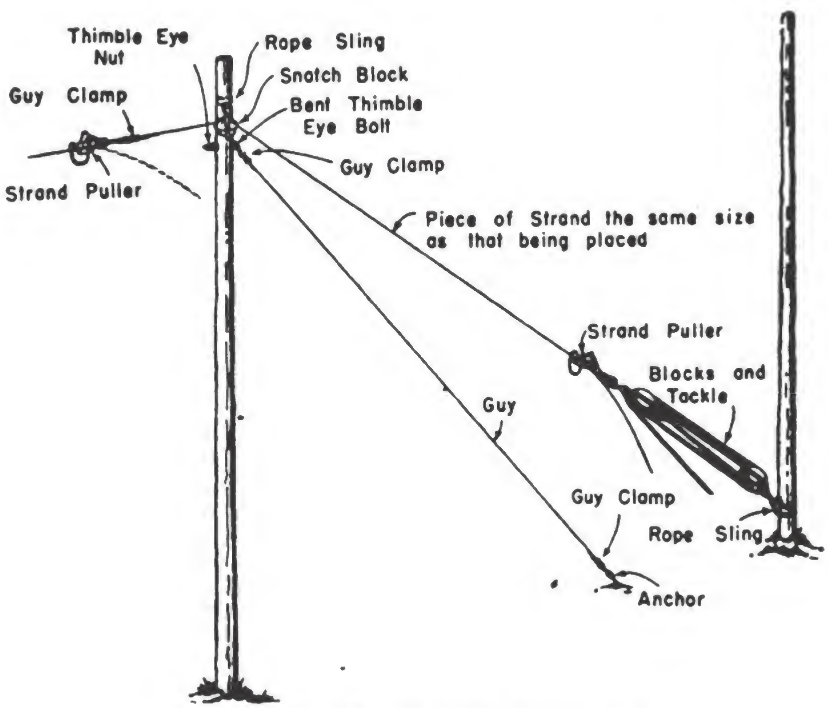


Figure 307.—Tensioning the messenger.

and tackle. The strand puller provides a means of gripping the suspension strand while the block and tackle gives you added pulling power. This set-up is shown in figure 307. Notice that the pulling line is directed through a snatch block placed at the top of the pole. As a result, a direct-line tension can be placed on the suspension strand. This will prevent the strand from being pulled down out of the suspension-clamp grooves.

After the suspension strand is pulled to the specified sag it is dead-ended. In most cases, the strand is terminated on the eye-bolt used for the pole guy. The method of dead-ending the strand is the same as that used for the guy wire. That is, the free end of the strand is threaded through the eye nut, doubled back and clamped to the main part of the strand with guy clamps.

After properly dead-ending the messenger, the pulling apparatus is removed. Then the suspension clamps on each pole are fully tightened. It is best to start at the middle pole in the string and work outward.

PLACING THE CABLE RINGS

With the messenger up and tensioned properly, you are ready to string the telephone cable. You'll find that two methods are used to support the cable along the messenger. One method

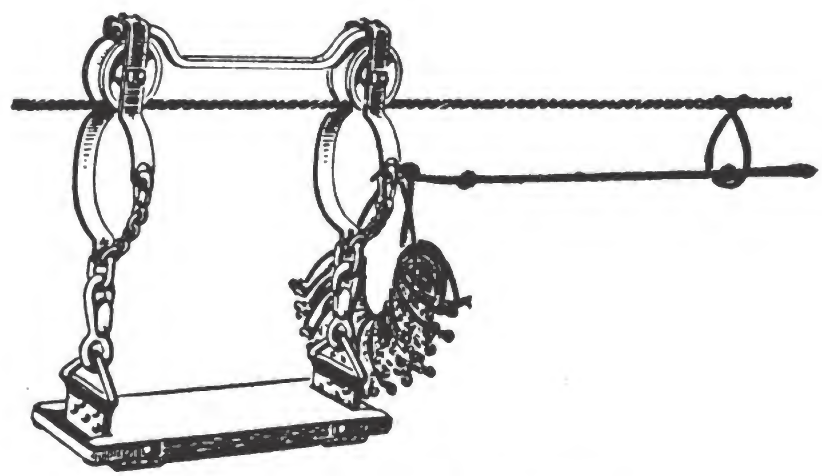


Figure 308.—Placing the cable rings.

uses CABLE RINGS, the other LASHES the cable to the strand. Let's talk about the cable-ring method first.

The cable rings are loops formed from one piece of metal. They are shaped in such a manner as to exert a strong tension grip when placed on the messenger. To get the cable rings on the messenger you will have to do a little high riding. You'll

use a CABLE CAR, one type of which is shown in figure 308. As you pull yourself along you will snap the cable rings on the messenger. A loop of wire attached to the cable car acts as a storage place for the cable rings.

Notice that DRAG LINE which is attached to the cable car. As you move along the messenger, the drag line is automatically threaded through the cable rings. Thus, you have set up a pulling-in line which can be attached to the telephone cable.

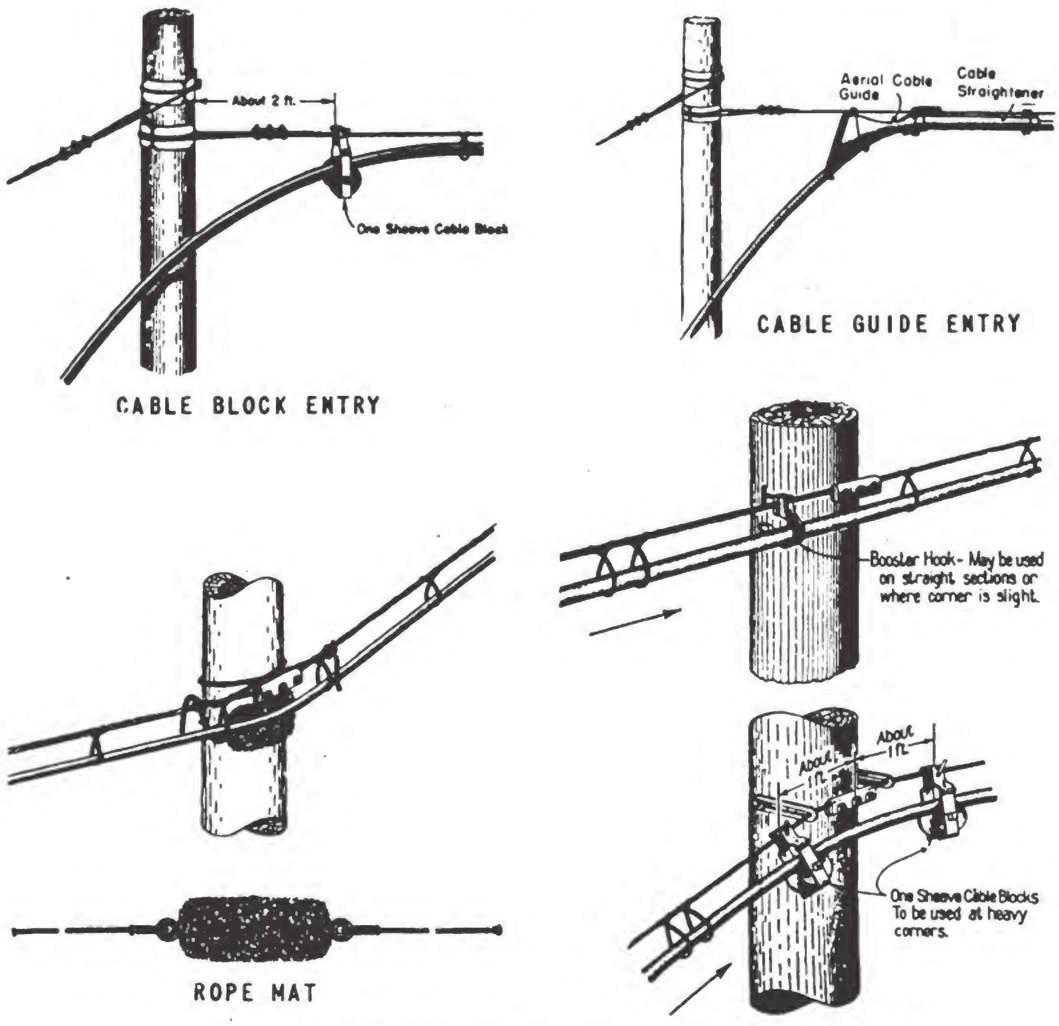


Figure 309.—Smoothing the way.

The drag line also assists in spacing the cable rings. Two knots, 20 inches apart, are placed in the drag line as shown in figure 308. It's easy enough to see how the correct spacing is attained.

PULLING IN THE CABLE

Telephone cable has to be handled with kid gloves. So, before you can pull it through the cable rings you must make certain preparations. To begin with, you have to set the cable

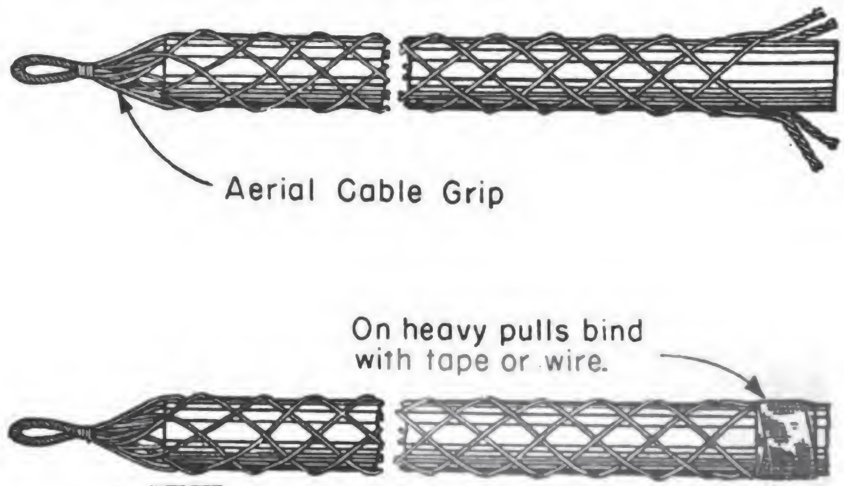


Figure 310.—Aerial cable grip.

reel up in the best spot. This is about 15 feet back of the entry point into the first cable ring. And, be sure you have the reel lined up with the messenger. Next, you've got to provide a smooth entry of the cable into the first ring. A cable block or cable guide (figure 309) is the answer. Then, you must be sure the cable can pass smoothly around curves in the line. Where the bend is away from the poles, cable blocks or booster hooks are used. Where the pull is against the pole, a rope mat comes in handy. Both of these methods are illustrated in figure 309.

Pulling in the cable now becomes a simple matter. About 6 feet of the cable is unwound from the reel and an AERIAL CABLE GRIP attached to it (figure 310). The pulling-in line, in turn, is fastened to the grip and pulling power is applied to the far end of the line. A snatch block placed at the end of the line will help guide the pulling-in line.

LASHING THE CABLE

The second method of attaching the cable to the messenger is by lashing. A wire is spirally wound around the cable and messenger, lashing the two tightly together. Although the

lashing wire may be wound by hand, it is usually applied with a LASHING MACHINE or CABLE SPINNER.

A typical lashing machine is shown in figure 311. You ride along in the bucket seat to provide dead-weight. A hand-crank may be used to propel the machine along, or it may be pulled from the ground. As the machine moves forward the revolving spinner head spirally winds the lashing wire around the cable and messenger.

Figure 311.—Lashing-machine operation.

Naturally you will have to bring the cable up to the messenger before the lashing can be applied. There are two methods that you can use. One way of doing it is to first string the cable through temporary cable rings. Then as the lashing is applied, remove the rings. In the second method, the cable is brought up to the messenger and lashed in one operation. A truck carrying the cable on a reel moves along the string. The cable is payed up to the messenger through a cable guide, while the lashing machine follows right behind.

OUTSIDE TELEPHONE TERMINALS

The job of the telephone cable is to carry the wires between subsets and switchboard. One cable, for example, may serve

as many as 500 telephones. Since these phones are scattered throughout the area, it is necessary to splice into the cable at certain terminal points. The wires from the cable are brought out at these terminal points and connected into terminal boxes. Then, outside drop wires are distributed from the terminal boxes to the subsets.

Splicing telephone cable means breaking into the lead sheath. Great care must be taken in this operation to insure a moisture-proof seal as good as the original covering. So you can expect that the telephone-cable terminal box, in turn, will be specially constructed. In figure 312, a terminal box is shown mounted on a pole. It has not yet been spliced into the main cable.

On opening the front of the terminal box, you would find a panel with binding posts, nuts, and washers. The drop wires

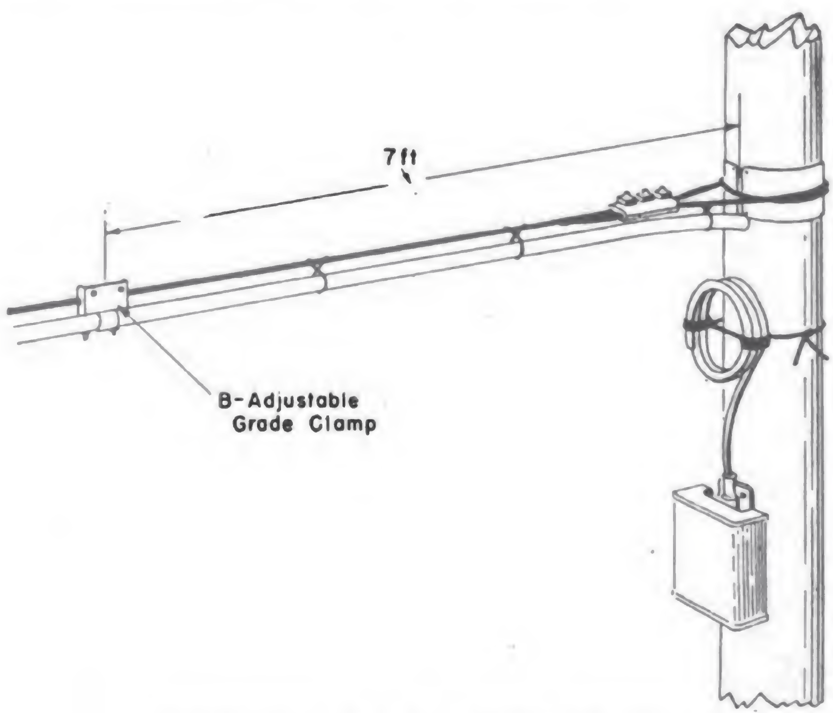


Figure 312.—Aerial-cable terminal box.

from the subsets are attached to these binding posts. Now, how are these binding posts connected to the wires in the main cable? The answer is in that short cable or stub which you see coming out of the back of the terminal box. This lead-sheathed cable stub comes attached with each terminal box. The wires

in the stub are brought out in the back of the box and permanently connected to the binding posts. Splicing the stub into the main cable then provides a moisture-proof seal all the way from the binding posts to the cable.

Mounting the Terminal Boxes

You will have the job of installing the terminal box on the pole. In most cases, it is set beneath the main cable, as shown in figure 312. The terminal box itself fits onto a mounting plate or bracket which is attached to the pole. This bracket is pictured in figure 313. Four drive screws hold it securely to the

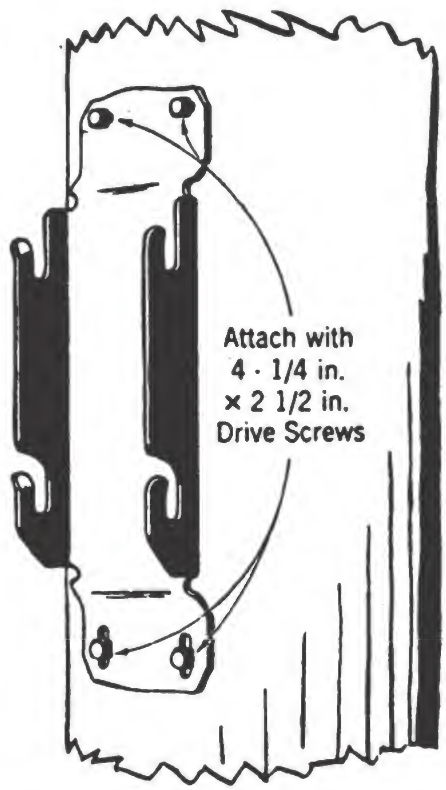


Figure 313.—Terminal mounting plate.

pole. The terminal box then slips into those four notches which you can see in the mounting plate. A snug fit between box and plate is maintained by four set screws.

UNDERGROUND CABLE

Telephone cable isn't always strung overhead. Another safe place for it is under the ground. Burying the cable directly in

the ground is one quick way of doing it. Another more permanent method is to place the cable in underground ducts or conduits.

Direct burial of the cable has its advantages—and disadvantages. As its main advantages you can list simplicity and ease of construction. For its disadvantages you can point to the fact that the cable is in direct contact with the earth. This might lead to mechanical damage or the possibility of corrosion of the lead sheath. Locating cable faults would also be rather difficult. And if additional cable were required, a new trench would have to be dug.

Placing cable in ducts has its advantages and disadvantages, too. The big advantage is the protection offered the cable. And, of course, the system is a permanent one which allows cable to be pulled in or replaced whenever needed. The main disadvantage of a duct system lies in its initial preparation. It must be carefully engineered and requires a certain amount of skill in construction.

DIRECT BURIAL METHOD

Direct burial of the cable requires three steps: (1) digging a trench; (2) placing the cable in the trench; and (3) backfilling or replacing the dirt in the trench. Since cable only comes in definite lengths, there will have to be points in the system where additional cable can be spliced on. This either involves bringing the cable above the ground or into underground splicing chambers.

The trench itself should be no wider than is necessary to lay the cable. You'll either dig the trench by hand or be lucky enough to have a trenching machine do the job. The depth of the ditch usually ranges from 18 to 30 inches.

The cable is laid directly in the ditch from a reel. The reel is mounted on a trailer which is pulled over the trench right-of-way. Pulling power for the trailer can be furnished by the trenching machine—if it is available.

After the cable has been laid in the trench, the excavated dirt is replaced. You can save yourself a lot of sweat if you can get

a bulldozer or scraper to do the backfilling. And a caterpillar tractor tread will do a good job of dirt packing. Just be sure that no rocks get into the bottom of the trench. They may damage the cable.

FACTS ABOUT UNDERGROUND DUCTS

Constructing underground duct (conduit) systems calls for a little more work than the direct burial method. If you were to list the steps, it would look like this:

1. Digging the trench.
2. Laying the conduit in the trench so as to form a continuous tunnel.
3. Building splicing chambers (manholes) at intervals along the line.
4. Refilling the trench with dirt.
5. Pulling in the telephone cable.

Two types of conduit are used. They are VITRIFIED CLAY and ASBESTOS-CEMENT. The vitrified-clay conduit has a square form while the asbestos-cement type looks like ordinary pipe. In either case, the joining process consists of connecting short lengths of conduit. The joints of the vitrified-clay conduit are sealed with mortar. A special coupling keeps the asbestos-cement conduit lengths together.

The trenches require a little special care in their construction. They should be dug in such a manner that they slope towards the manholes. This will provide a drainage system for any water that might seep into the trenches. If the water were allowed to collect in pockets it might freeze and damage the cables.

Installing Clay Conduit

As the sections of clay conduit are fitted together, the joints are sealed with cement mortar. Someone thought of a bright way to apply this mortar. Instead of throwing it on with a trowel, the mortar is placed in a wrapping of cheesecloth. This mortar bandage can then be easily wrapped around the conduit

joint. The cheesecloth helps retain the water during the setting of the cement. The final result is a firm concrete seal.

Figure 314 shows you the four steps in laying and joining clay conduit. Before the next section of conduit is brought into the trench, you will set up the mortar bandage as illustrated in step one. The distance from the preceding conduit to the next joint is marked on the ground. Then the mortar

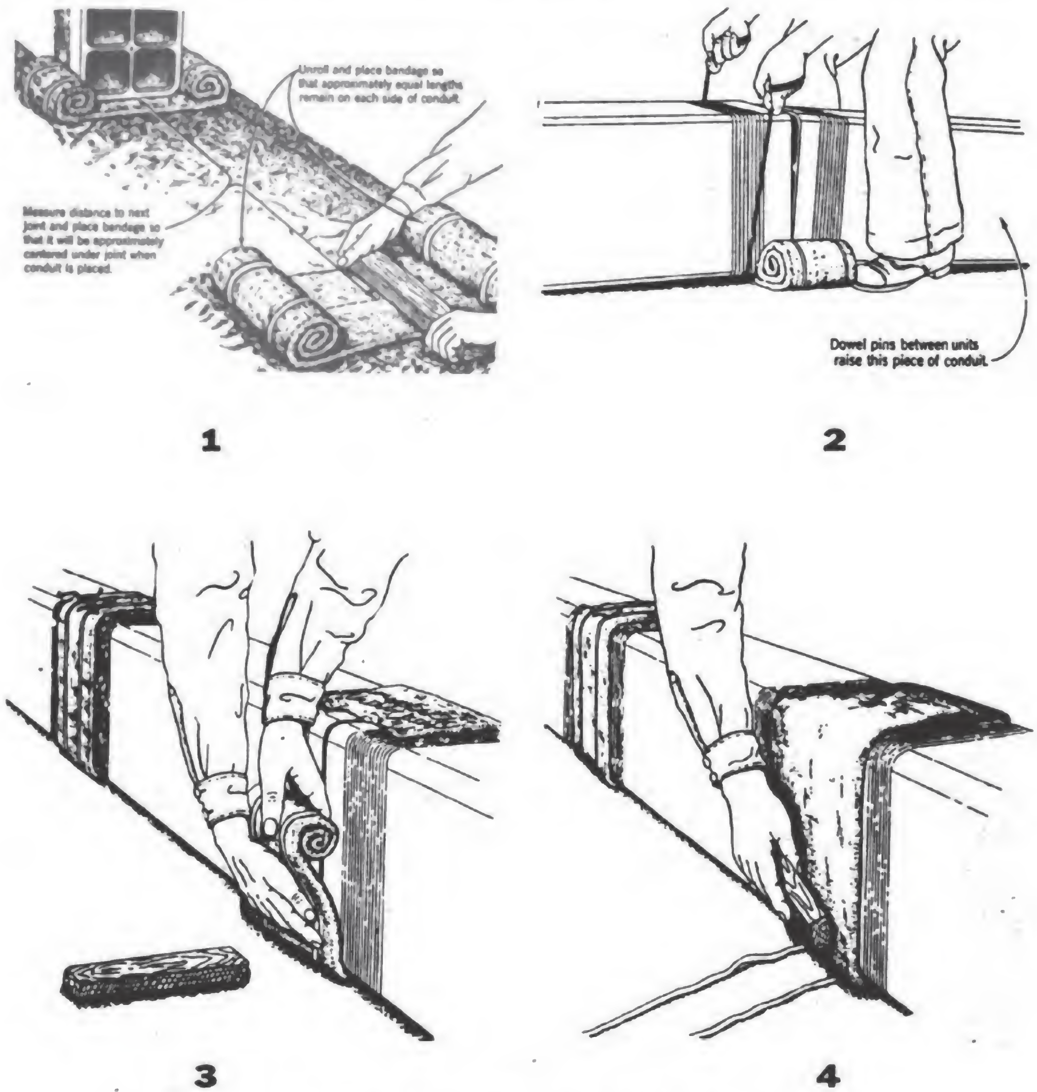


Figure 314.—Laying clay conduit.

bandage is centered over this mark. Be sure that the bandage is unrolled so that equal lengths remain on each side of the conduit.

Now the next section of conduit is brought into the trench. It may be lowered by hooks or by a supporting rope passed through its entire length. After you get the conduit into the trench, you will aline it with the adjacent unit (step 2). A sling of small rope will help in this operation. Notice that both sections are lifted clear of the bandage. Small steel dowel pins inserted in the holes in the ends of the conduit help in the alining process. After the two ends have been brought together, they are placed back on the mortar bandage.

Applying the bandage to the joint is the next step. Each end of the bandage is unrolled and brought up the sides and over the top of the joint. In step 3, one end is shown in this position, while the other is in the process of unrolling. As each side is drawn up, it is smoothed against the joint. You'll find that the edge of a small block of wood will help in applying an even pressure. This smoothing operation is shown in step 4 of figure 314.

As the last step you will tie the tapes which are on the outside of the bandage. You can see the result of this tying in operation in the preceding joint of step 4.

Installing Asbestos-Cement Conduit.

A special coupling is used to join asbestos-cement conduit. You can get a close-up of it in view *A* of figure 315. Installing the conduit is easy. All you have to do is fit the coupling onto the previously laid length of conduit. You can get a secure fit by placing a wood slat against the coupling and tapping it lightly with a hammer. Then the next length of conduit is fitted into the open end of the coupling. It can also be tightened up against the coupling by the use of the wood slat and hammer.

Since asbestos-cement conduit is a single duct affair, you can expect several conduit lines to be laid in one trench. They are placed side-by-side and in tiers. As each row of conduit is laid in the trench, a layer of dirt is placed over them. This forms a new trench bottom on which the next tier of conduit may be laid. The earth should be firmly tamped under and around the conduit. View *B* of figure 315 shows you how it's done.

Figure 315.—Asbestos-cement conduit.

Facts About Manholes

You'll remember that laying the conduit is just one phase of underground cable construction. You still have to pull the telephone cable through the conduit. And that's where manholes come in handy. They act as points where the cable may be easily installed in the ducts. They also provide a chamber where splicing of cable runs can be easily accomplished.

The manhole is constructed of either concrete or brick. An opening in the top provides an entrance to the splicing chamber. Support for the cables as they pass through the manhole is provided by cable racks. These racks are built into the side-walls of the chamber. As the cables enter the manhole from the ducts, they are trained along the side-walls and placed on the cable racks.

Cleaning the Duct

The duct will need a good cleaning before the cable can be pulled through. All the dirt and cement that entered during construction must be removed. Anyone of the rodding tools shown in figure 316 may be used for the job.

What you do is simple enough. Starting at one manhole you push the rodding tool through the duct until it emerges at the next manhole. The rodding tool is attached to a short length of rod. As the tool is pushed into the duct, additional lengths of rod are coupled together. When the rodding tool appears at the next manhole, the whole assembly can be pulled through. A threading wire is fastened to the last section of rod. When this last section is pulled through, the threading wire will come with it.

PULLING IN THE CABLE

After the duct has been thoroughly rodded, the telephone cable is pulled in. Your first job will be to install a pulling rope in the duct. It's easy enough to do since you already have the threading wire running through the conduit. Just attach the pulling rope to the threading wire and pull the wire out at the adjacent manhole. You stop when the pulling rope appears at the manhole.

Now you have a rope stretched through the conduit between the manholes. Attach one end of the rope to the pulling source and the other to the cable and you are all set to go. The cable reel is placed as shown in figure 317. A cable feeder, or flexible tubing, guides the cable smoothly into the duct entrance. Notice that the cable is fed from the top of the reel.

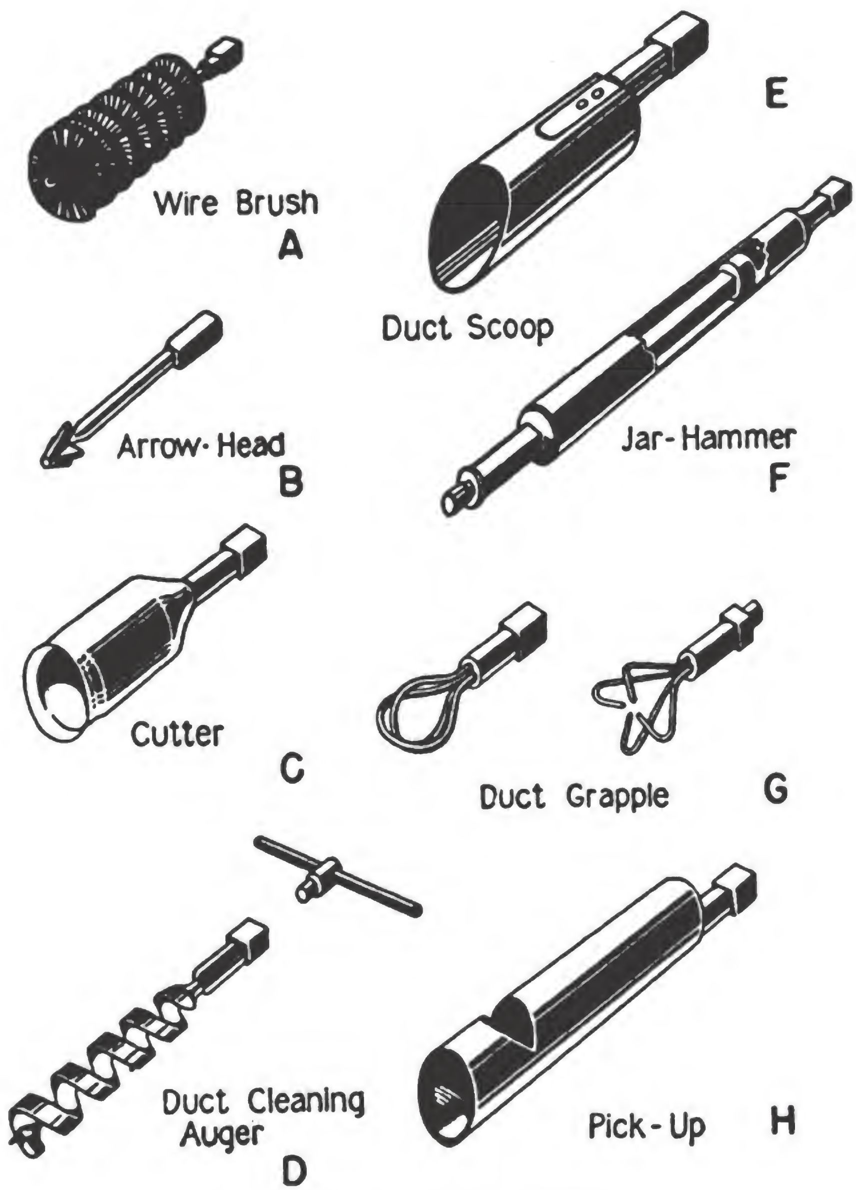


Figure 316.—Rodding tools.

The pulling rope is connected to the cable by means of a cable grip. That's the same device you used in pulling in aerial cable. At the other end of the line, the rope is connected to a

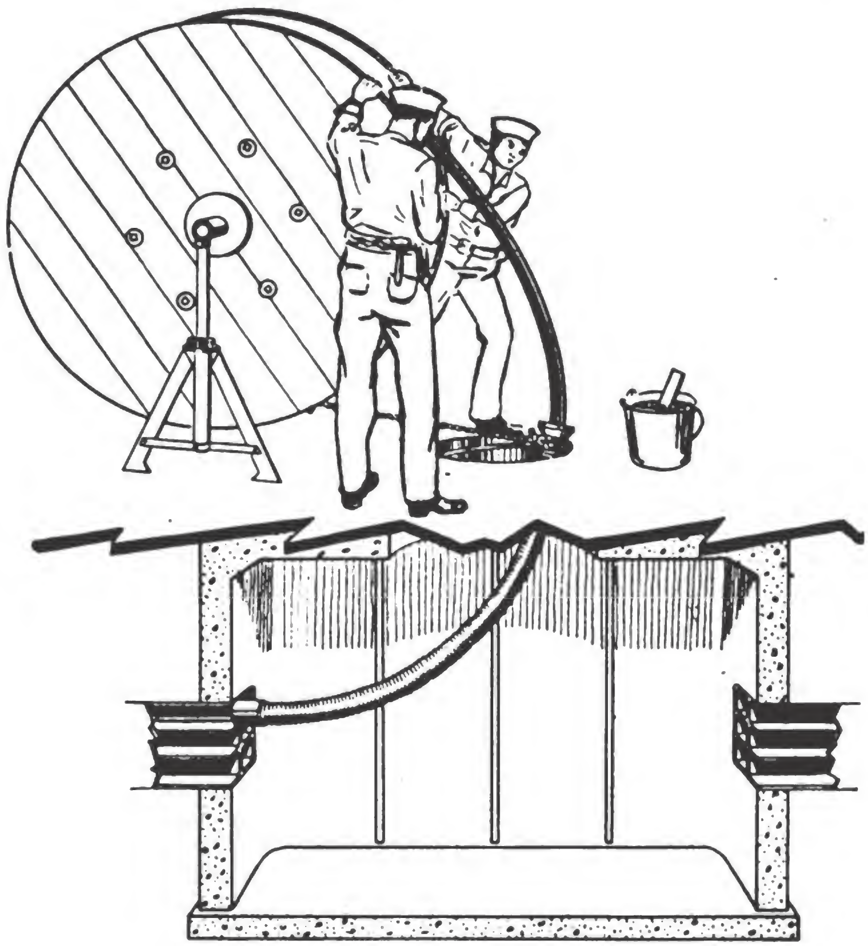


Figure 317.—Feeding the cable into the duct.

power winch on a truck. A straight line pull can be attained with use of a sheave attached to a pulling frame.

SUMMARY

Pole construction methods are similar for telephone and power lines.

Stringing field wire is a quick, temporary method of connecting telephones.

There are three general methods of installing permanent telephone lines: open wire, aerial cable, and underground cable.

Installing open wire is the stringing of individual bare-wire line attached to insulators on crossarms.

Installing aerial cable involves the stringing of a messenger to which the telephone cable is attached by cable rings or lashing.

The messenger is supported at the pole by means of a cable-suspension bolt and a cable suspension clamp.

Cable rings between poles are placed 20 inches apart.

Cable may be lashed to the messenger directly or after the cable has been pulled into cable rings.

The terminal box is the "tap" at the pole to which a pair may be connected to a subset by means of a drop line.

Underground cable may be laid directly in a trench or placed in a duct system.

Burying cable directly in the ground has the disadvantage of being inaccessible for repairs, replacement, or the future addition of larger cable.

Generally, the two types of conduit used for underground duct systems are vitrified clay and asbestos-cement.

Manholes are used for "pull-points," splicing chambers, and as the underground terminal box.

A rodding tool is used to clean the dirt and excess cement from the duct prior to pulling-in the cable.

QUIZ

1. What type of telephone wire is used for temporary installations?
2. Give the four main operations of stringing open wire.
3. What type of insulation separates the wires in aerial cable?
4. What is meant by the term "messenger"?
5. What device is used to grip the suspension strand during tensioning operations?
6. Name two methods used to attach the telephone cable to the suspension strand.
7. When pulling the cable into rings, what protects the cable when it curves around and against the pole.
8. What two methods may be used to lash aerial cable?
9. What is the name of the boxes to which the drop wires are attached?
10. In most cases, is the terminal box mounted above or below the aerial cable?
11. What two methods are used to run underground cable?
12. Give five steps in laying cable in underground ducts.
13. What two types of underground conduit are used?
14. What is the name of the tool used to clean underground ducts?
15. Is the cable fed into the conduit from the top or bottom of the reel?

CHAPTER 14

INSTALLING THE TELEPHONE

FIRST, THE COMPLETE PICTURE

A telephone system can be divided into three major parts. First, there is the switchboard located in the CENTRAL OFFICE. Next comes the OUTSIDE PLANT. This consists of the wires which radiate from the switchboard. The wires may be strung openly on crossarms or be contained in lead-sheathed cable. And, last, but not least, there is the INSIDE PLANT. You can probably guess what it is composed of. That's right, it's the telephone and the wires which connect the phone to the outside plant.

UP TO NOW

Now, here's how the picture shapes up so far. The switchboard has been installed in the central office. And you have

just finished the construction of the outside plant. This, in effect, brings the switchboard within reach of the telephones in the area.

But, within reach isn't the whole story. A direct connection must be made between the switchboard and the phones. You do this by running a pair of wires between each phone and their respective pair of wires in the outside plant. In other words, you complete the telephone system by installing the inside plant.

STEP BY STEP PLAN

Have you ever watched a football game? The team on the offensive never trusts to luck that the play will succeed. Instead, the players go into a huddle and talk over the play so that each will know what he is to do. That avoids confusion because a definite plan of attack is presented.

Maybe comparing a football game to wiring the inside plant is stretching it a bit. But don't you agree it's a good idea to have a step-by-step plan? You can get a bird's-eye view of the whole job and know exactly what you're supposed to do.

Here, then, are the steps you will follow in installing a telephone:

1. Secure the drop wire to the pole and tap the drop wire to the designated pair of wires in the main run.
2. Span the drop wire from the pole over to the building wall.
3. Train the drop wire along the side of the building until the entrance hole is reached.
4. Bring the drop wire through the entrance hole into the building.
5. Connect the drop wire to the input end of the protective device (fuses and lightning arrester).
6. Connect the inside house wire to the output of the protective device.
7. Run the inside house wire along the walls and ceilings to the subset location.
8. Terminate the inside house wire at the connecting block.

9. Place the subset and attach its wires to the connecting block.

10. Check the installation.

TYPES OF WIRE

You've probably noticed in the steps outlined above that there was a change-over in the type of wire used. That is, DROP WIRE was used from the pole to the building. And then after entering the building, the circuit was continued with INSIDE HOUSE WIRE. The difference between the two is in their protective coverings.

Drop wire is exposed to the wind and rain. Each can cause plenty of damage unless the wire is protected. So, the two conductors of the drop wire are first insulated with a tough rubber compound, and then covered with a weather-proof cotton braid. And there are two forms of drop wire used. One is known as TWISTED PAIR and consists of two conductors spiraled together but separately covered. The other is termed PARALLEL DROP. Its two wires are run parallel to each other under one braid covering.

Inside house wire is a twisted pair, each wire being insulated with rubber. Normally, no protective braid covering is used since the wires are run inside the building. However, under certain conditions where dampness is encountered, a braid-covered wire is employed.

AT THE POLE

Okay. Now that you know the general plan of attack, suppose you find out how each step is accomplished. Since you're a logical fellow, you'll want to start with step one. It involved securing and connecting the drop wire at the pole. Since you're also a smart fellow, you know that in this step two different methods of connecting the drop wire must be described. In case Joe Doaks doesn't understand why, you can explain it to him easily enough. You'll just tell him that the wires in the main run may be strung openly on crossarms or be contained in a lead-sheathed cable. Thus, in one case, the

drop wire will be connected directly to a pair of open wires. Where cable is involved, however, the drop wire will be connected to a pair of terminals in a terminal box.

Before you make your drop-wire connections, you'll have to secure the wire to the pole. This involves securing the wire at the jumping-off point and then training it back to the connecting point in the main run.

The Jumping-Off Point

Running the drop wire between pole and building presents a problem. It must be kept under tension to insure a definite amount of sag. And yet its dead weight should produce no strain on the rest of the run. An interesting device called a DROP-WIRE CLAMP solves the problem.

Figures 319 and 320 will give you a pretty clear picture of the clamp installation. However, for a close-up view suppose you look at figure 318. Notice that the clamp consists of two

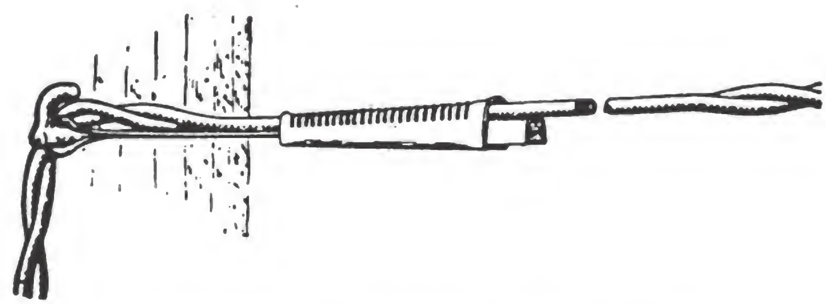


Figure 318.—Drop-wire clamp installation.

parts—a sleeve and a wedge. The sleeve tapers down to a narrow opening at one end. The wedge is secured to a copper-wire loop which attaches to the support point on the pole.

To install the clamp, here's what you do:

1. Place a hook attachment at the jumping-off point. A DRIVE HOOK is used if the drop wire leaves the side of the pole (figure 320). Where the drop wire takes off from the crossarm, use a GUARDARM HOOK (figure 319).
2. Secure the copper wire loop to the hook support.
3. Place the sleeve over the drop wire and slide it firmly

up on the wedge. Be sure that the tapered end of the sleeve is toward the hook support.

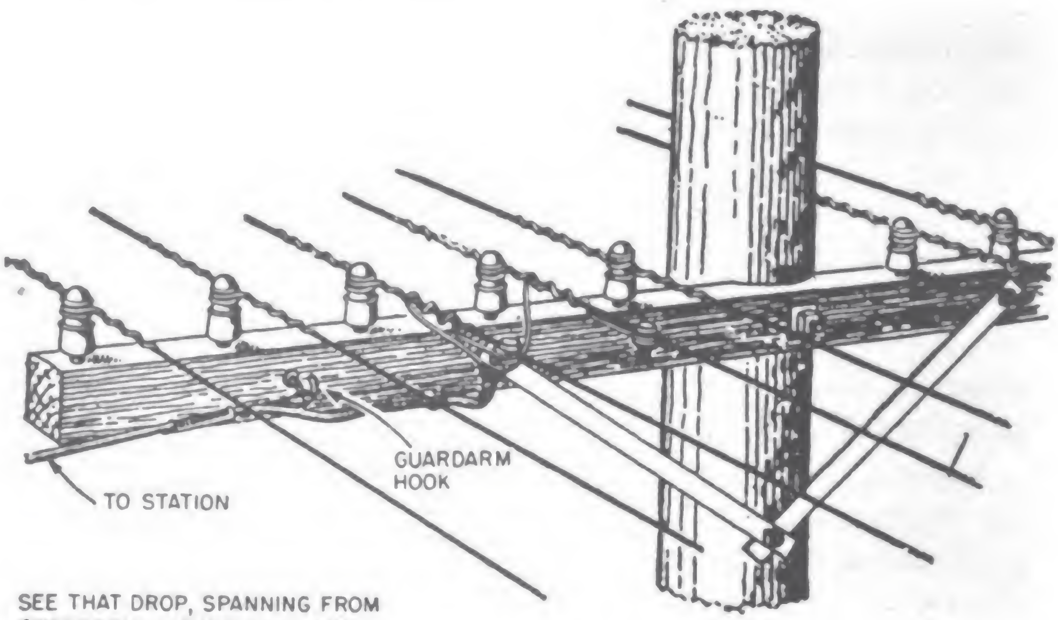


Figure 319.—Open-wire connection.

Now, when the other end of the drop wire is attached to the building, the dead weight of the span will produce a wedge fit at the clamp.

Training the Wire on the Pole

The drop wire has been secured to the cable clamp. Now you're all set to train the wire back to the connecting point in the main run. Where open wire is concerned, the drop wire is trained under the crossarm to the connecting point. Figure 319 shows how this is done. Bridle rings may be used to support the drop wire along the crossarm. The bridle ring has an open spiral eye. This permits the drop wire to be slipped into the ring, after it has been screwed into the crossarm.

Where the drop wire is to be connected to a terminal box, a slightly different arrangement is used. The terminal box is located on the side of the pole, below the cable clamp installation. So you'll have to bring the drop wire down the side

of the pole to the connecting point. Bridle rings are used to support the drop wires on the pole as shown in figure 320. Notice the arrangement of the rings just below the box. Can you guess why the drop wires are trained in this fashion before they enter the terminal box? Just in case you can't, here's

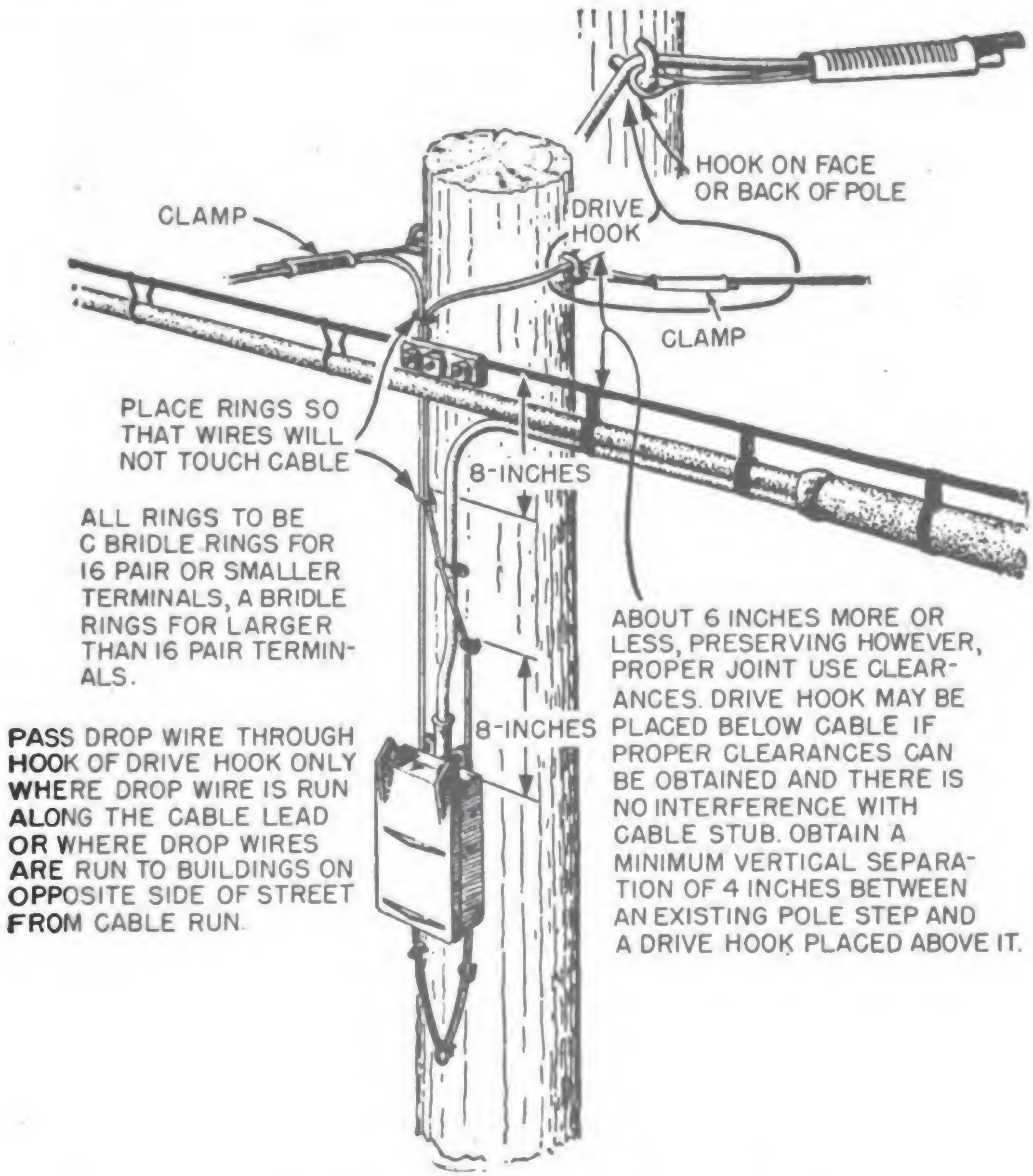


Figure 320.—Drop wire runs from a terminal box.

the answer. It provides each drop wire with enough slack to permit future changes in terminal connections.

Open-Wire Connections

The wire chief will tell you which pair of wires to use in the main run. At your working position you will prepare the end of the drop wire for splicing. This consists of separating the two conductors and removing the insulation from their ends.

It might be a good idea at this point to look at figure 14-2. You can actually see how the connections are made. Each conductor of the drop wire is wrapped around the main run wires for about three turns and extended out to the connecting point. The joint is made with a solderless connector. The particular type of connector shown uses a slotted bolt and nut and washer assembly. The main wire is placed in the slot while the bared end of the drop wire is wound around the bolt between two washers. Be sure that the drop wire is around the bolt in the direction that the nut tightens. Turning the nut down will then produce a firm joint.

Cable Terminal Connections

Making drop wire connections to telephone cable is easy. All you do is tie the drop wire to a pair of binding posts in a terminal box. Each pair of binding posts, in turn, connects to a pair of wires in the main cable. The wire chief, of course, will designate which pair of binding posts to use.

Figure 321 shows you how the connection is made. Both a parallel and twisted-pair drop-wire installation is shown. Notice that the wires are brought into the terminal box through the bottom. They feed into channels which run the length of the binding post panel. A FANNING STRIP separates the channels from the binding posts. Thus, the drop wire must go through the fanning strip to reach the terminals. Holes are provided for this purpose and help to maintain an orderly wiring arrangement.

Proper preparation of the ends of the drop wire is important. First of all, a neat connection must be made. To do this it will be necessary to cut one conductor shorter than the other. A check of the binding post positions will show you why—the two posts which make up a pair are in alternate rows. And then there's the problem of possible shorts developing in the box. You can

see that the clearance between posts is small. To prevent bare conductors from touching adjacent posts you should remove only a small amount of insulation. Skin off just enough insulation to permit the bare conductor to hook around the binding post and extend back one-eighth inch from the washers.

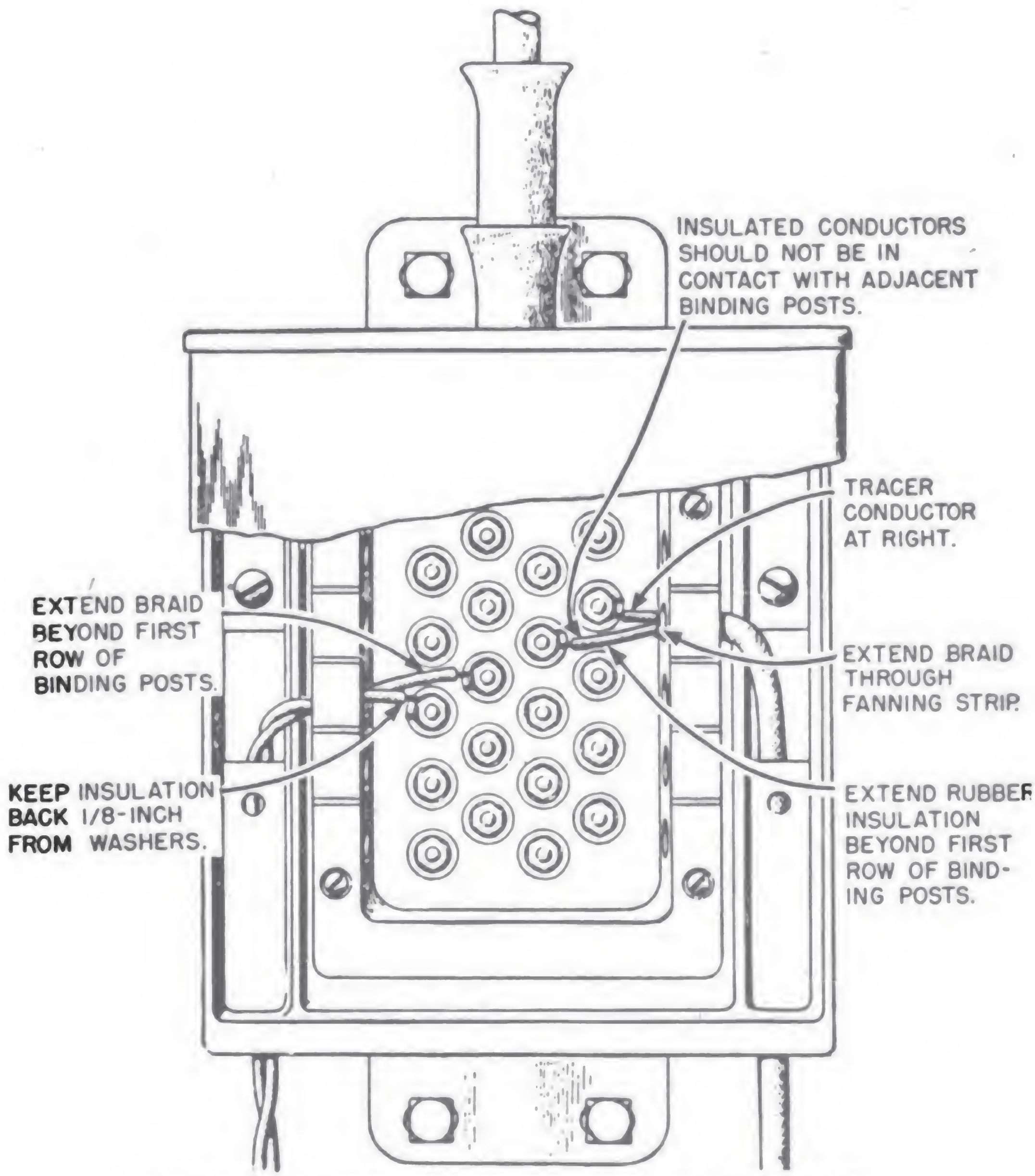


Figure 321.—Connections at the terminal box.

Again, be sure that the conductor hooks around the post in the direction which tightens the nut. Where two conductors are to be placed on one post, hook the first conductor under the lower washer. Then place the second conductor between the upper and lower washers. Turn the nut down firmly to insure good conduct.

ON THE BUILDING

There's nothing more you can do on the pole, so hustle down, take off your climbers, and get over to the building wall. Your job there is to attach the drop wire to the wall and then carry it over to the entrance hole.

You're going to get a lot of help from the wire supports shown in figure 322. Which one do you use where? Well, that depends to a great extent on what's available and the composition of the building wall. For example, you'll notice that some of the supports are uninsulated while others are insulated. Generally,

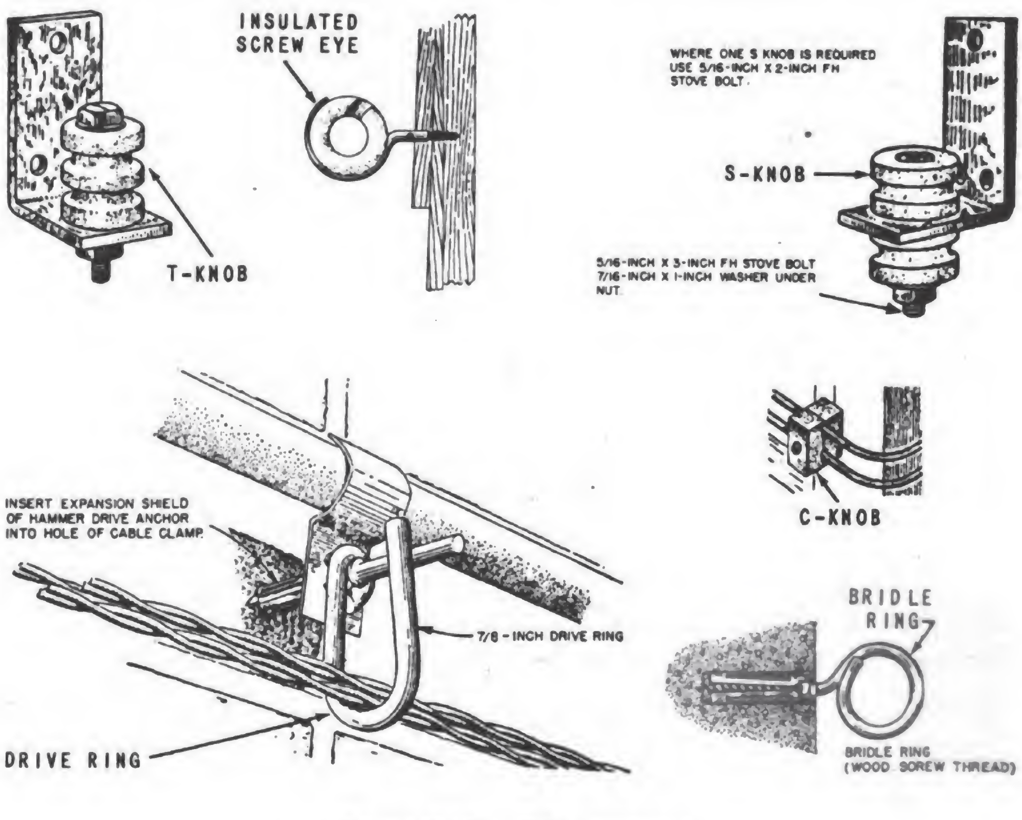


Figure 322.—Wire supports.

you will use the uninsulated supports on brick and tile walls. However, if you're working on a wood frame or other conducting and flammable material be sure to use an insulated support.

Those supports in figure 322 must be securely attached to the building. Suction cups won't work, but nails, screws, and bolts will. However, you're going to have to use your head here. Not as a hammer, of course, but as a thinking device. You see, you may have to attach the support to a brick wall, or hollow tile wall. Naturally, you can't place a nail screw, or bolt directly into that kind of material. ANCHORS and TOGGLE BOLTS will have to be used.

Suppose you are installing bridle rings on a brick wall. The first thing you do is drill a hole at the point of attachment with a STAR DRILL. Then you insert a SCREW ANCHOR in the hole. Next you screw the bridle ring securely into the anchor. The screw threads act as a wedging device and expand the split sides of the anchor firmly against the brick. The completed job can be seen in the bridle ring view of figure 322. By the way, don't think that anchors are only made to take screw threads. There are also nail and bolt types.

On a hollow tile wall you'll use toggle bolts. Your first step is to drill the hole at the attachment point. Then you insert the toggle bolt into the hole. The toggle nut is made of two pivoted wings under spring tension. The wings may be folded against the side of the bolt so that the whole affair can be slipped through the hole. When the toggle reaches the hollow space behind the hole it will spring open and bear against the inside wall. Then you simply screw in the bolt. The *C*-knob view in figure 322 shows you the end results for hollow-tile wall construction.

You may find it necessary to run drop wire on a quonset hut. But don't start getting ideas about drilling holes in the sheet metal. There's a much easier way. Just attach the wire supports to the sheet metal with a nail. Where do you drive the nail? That's easy, too. It's at the same point where the sheet metal is secured to the metal ribs of the building. Simply look for a row of nails going right up the side and over the top of the hut. You'll find each row spaced four feet apart.

By the way, since this is a metal building, be sure you use insulated knobs.

Suppose you had to install drop wire on the frame building shown in figure 323. This is how you go about it. First, you attach the wire supports. Using a ladder, place an *S* knob and drop-wire clamp at the initial attachment point. Moving

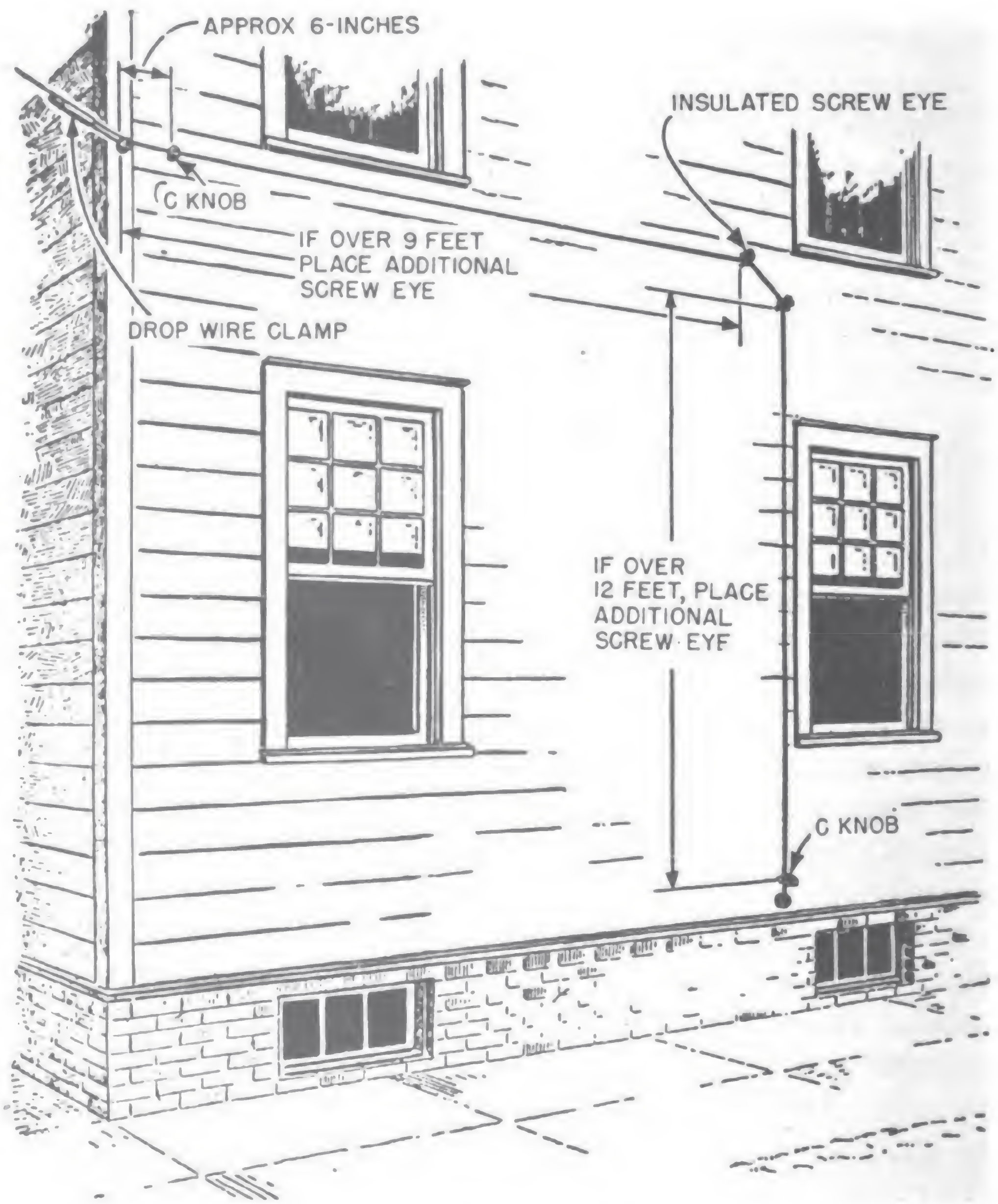


Figure 323.—Typical drop-wire run.

about 6 inches over, screw in a *C* knob. Then, in the same horizontal line, you attach an insulated screw eye. Now, scoot down and over about 6 inches and screw in another insulated screw eye. This screw eye should be in a vertical line with the entrance hole. About 12 inches above the entrance hole, place a *C* knob.

After attaching the supports you run in the drop wire. At the drop-wire clamp, pull the wire to the proper sag and then wedge it in. Run the drop wire over the *S* knob and secure it with a length of tie wire. Continue the drop wire through the groove of the *C* knob. Tighten the *C* knob down. Next, slip the wire into the insulated screw eyes and bring it down to the last *C* knob. Place the wire in a groove of the *C* knob, pull to a slight tension, and tighten the *C* knob. Now you're all set to send the wire into the building.

THROUGH THE ENTRANCE HOLE

You know by now that you'll be working on all types of buildings. So when you construct the entrance hole you're going to have to use the right tools. For example, boring a hole through a wood frame requires a wood bit and brace. If there's a brick fire stop you'll have to change over to a star drill and ball-peen hammer.

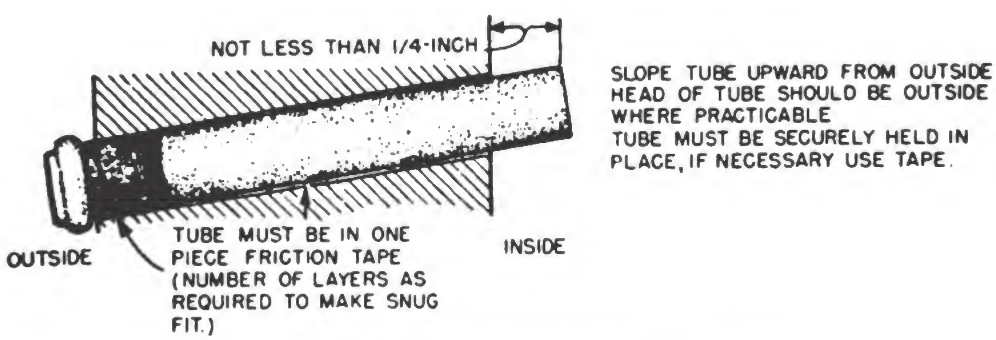


Figure 324.—Porcelain tube in entrance hole.

It's a good idea to slant the hole upward from the outside. This will prevent water from entering the building. A porcelain tube may be inserted in the hole as shown in figure 324. A few layers of friction tape will provide a snug fit. Be sure the end

of the tube extends at least one-fourth inch past the inside wall.

CONNECTING TO THE PROTECTOR (INPUT)

The drop wire extends from the pole to the building, and then over to the entrance hole. It's definitely exposed to electrical hazards such as lightning discharges and crosses with light and power lines. That means possible damage to the telephone equipment, and the chance of personnel being injured. So, it's necessary to place protective devices in the line.

You'll find the protective device consists of a fuse and a lightning arrester for each of the drop wire conductors. The fuses are inserted in series with the line while the arresters are placed between the lines and ground. These are the same type of fuses and arresters described in chapter 12.

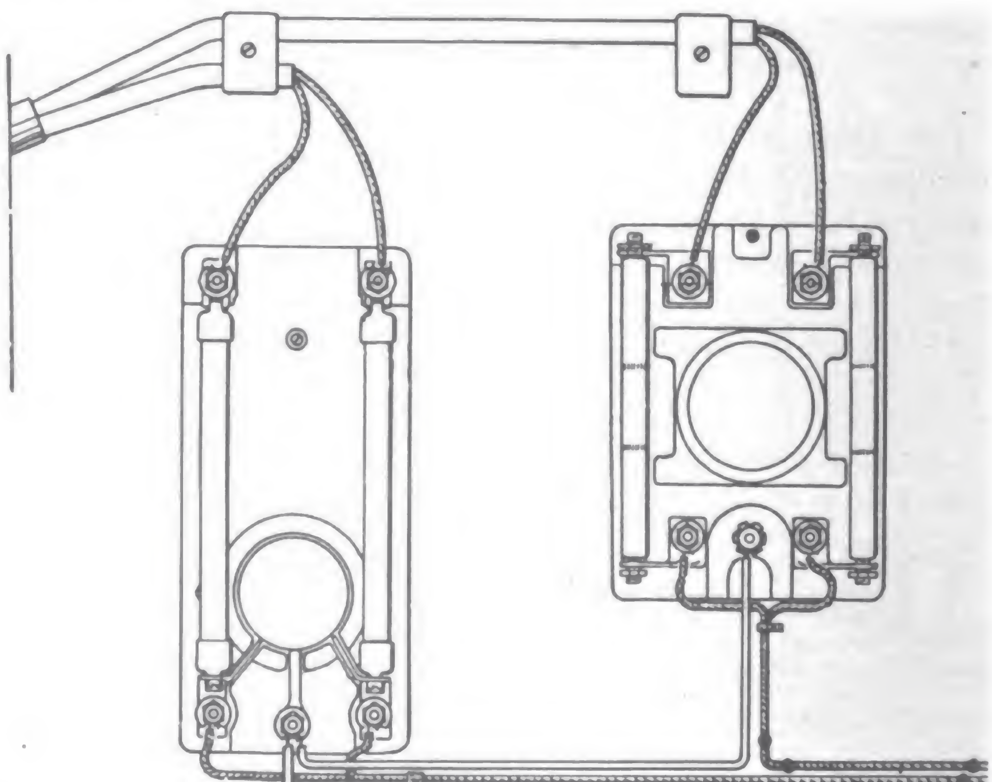


Figure 325.—Protective device connections.

Figure 325 shows the wiring connections at the protective device. This happens to be a two-phone installation. So,

naturally, you'll find two of everything—two drop wires, two protectors, and two inside house wires. You've probably noticed by now that the two protectors look slightly different. That's because each is made by a different manufacturer. The one on the left is a COOK B-7, the one on the right a WESTERN ELECTRIC 98-A. However, you've also noticed that essentially they contain the same parts. So you can focus your attention on the Cook B-7 while the explanation of the protector installation is made.

Before you make your connections you've got to mount the protector. It is a one-unit affair with the fuses and arresters placed on a porcelain block. Mounting holes are provided at each end of the block. Thus, it can be secured directly to any solid surface. In some cases you might have to use a wood backboard. Just be sure that you keep at least 1 foot between the protector and light and power wires. And also be certain that the protector is mounted so that the fuses are side by side in a vertical line. After the protector is in place, attach a *C* knob about 4 inches above the input terminals.

Now bring in the drop wire through the entrance hole and clamp it in the *C* knob. Prepare the wire by removing the outer braid and skinning off about three-eighths inch of insulation from the ends. Leave about one-fourth inch of braid past the *C* knob. Hook the bare end of each conductor to one of the two input terminal posts on the protector. The bare ends of the conductors should circle the posts for about a three-quarter turn. Make sure the wires are hooked in a clockwise direction, then tighten the terminal nuts down.

It might be a good idea to set you straight on the protector location. Although only the inside protector has been discussed, you will find in some cases that the protector is mounted outside the building. For this purpose, the protector is inclosed in a metal can, which makes it completely waterproof. A mounting bracket provides the necessary support on the building wall.

CONNECTING TO THE CONNECTOR (OUTPUT)

Okay. Now suppose you step back a little and see what

you've accomplished by connecting the drop wire to the protector. Notice that any current which travels over the drop wires must go through the fuses before it can reach the output terminals. That's protection number one. And then there's the lightning arrester. You can't see the carbon blocks because they're under a protective metal cap. However, you can see the wires which lead from the arrester to each of the main wires. That middle lead is the arrester ground terminal. Any high potential on the line will be bypassed to ground before it can reach the output terminals. That's protection number two.

With all that protection, you can feel safe in connecting the inside house wire to the protector. It's simply a matter of stripping the insulation and attaching the wires to the output terminals. Figure 325 shows you that the output terminals are the outside binding posts on the bottom end of the protector.

But how about that center terminal? You know that it's supposed to be the ground terminal for the arrester. So let's not forget to connect it to ground. To do this you run a ground wire from the ground terminal to the earth. Of course, you won't stick the end of the wire in the earth. Instead, you attach it to a metallic object that is in close contact with the ground. A cold water pipe is your best bet but you can connect to a conduit or buried metal tank. However, if none of these are available you'll have to drive a ground rod.

The ground wire is a single conductor, insulated by a rubber coating. It is trained along the wall to the ground point connection by the use of small pipe straps. Figure 326 shows the end of the run at the water pipe. A ground clamp provides a low-resistance contact and attachment point for the ground wire. The clamp consists of a wide metal strap perforated with a number of holes. This allows a tight fit to be made on any size pipe.

It's simple to install the clamp. First remove the bolt and nut. Then wrap the clamp around the pipe with the wire lug facing outward. Next, insert the bolt through the holes which will give the tightest fit. Screw on the nut, hook the bared ground wire under the bolt head, and tighten with a screw driver. The extra portion of the strap should be removed.

Make a nick with side-cutting pliers and break the strap at that point. And don't forget that the pipe surface should be cleaned of rust and dirt before applying the clamp.

RUNNING THE INSIDE WIRE

Start lowering your flaps, fella, the end's in sight. The protector has been grounded and the inside house wire connected to the output terminals. All you have to do now is run the inside house wire to the telephone and connect the two together.

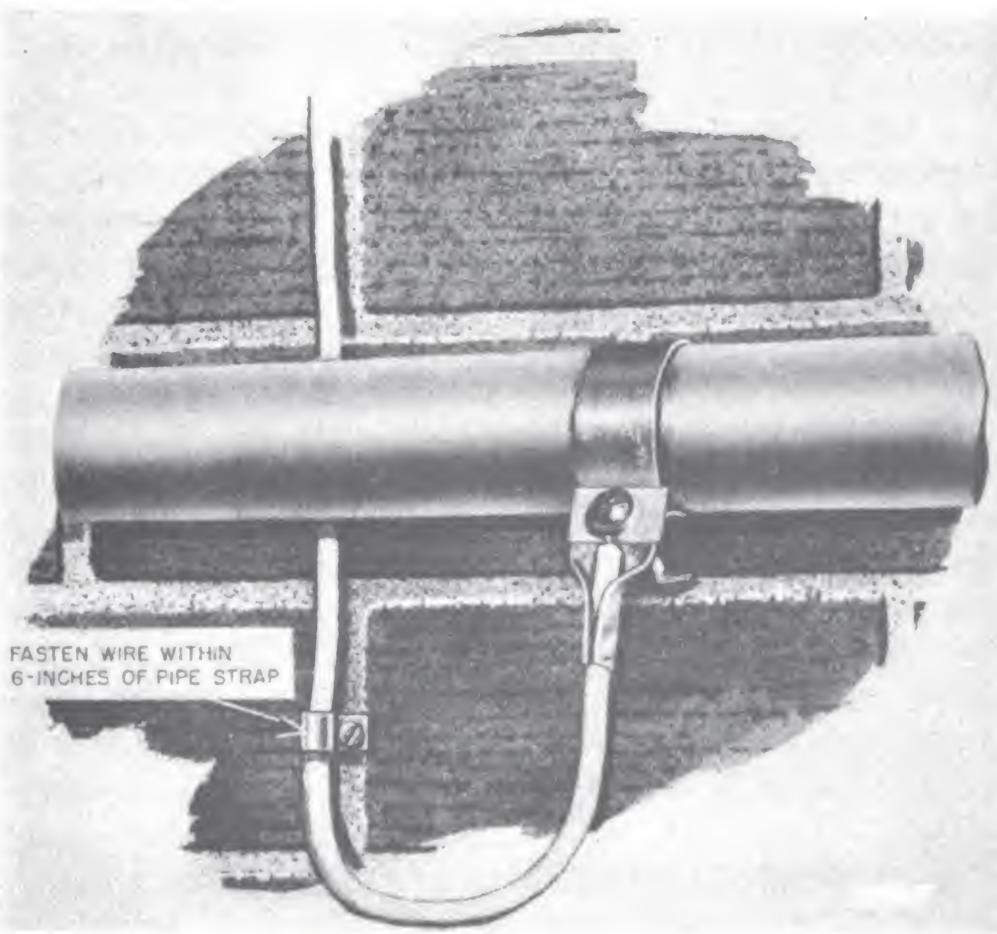


Figure 326.—Ground-wire clamp installation.

What makes things easy in running inside house wire is that you're dealing with a protected, low voltage circuit. As a result, you can use insulated staples or inside wiring nails

to secure the wire directly to wood surfaces. On concrete walls and ceilings, of course, anchors and drive rings will still come in handy.

The route that the inside wire takes between protector and subset depends on your good judgment and common sense. The important thing to remember is to make a neat-appearing run. That means installing the wire PARALLEL WITH OR AT RIGHT ANGLES TO THE BUILDING WALLS. And don't forget that some form of protection is needed whenever the wire is exposed to mechanical injury. A couple of layers of friction tape serves the purpose where the wire passes around sharp corners or over metal objects. If it is necessary to leave the walls and ceiling and run the wire over the floor, then use a flat metal raceway.

At the telephone location, you'll end the inside wire run on a CONNECTING BLOCK. Although there are different forms of connecting blocks their purpose is the same. They provide a test point and a convenient spot to connect the inside wire to the telephone cord. The one you'll work with most often consists of four terminal posts mounted on a small square composition base. A removable metal cover provides protection.

The inside house wire is brought into the back of the connecting block, wound around projecting lugs and then connected to the terminal posts on the front face of the block. This will take the strain off the wire. It will also provide enough slack for reconnecting the wire in case a bare end breaks off. Generally, the connecting block will be placed near the phone. The block can be mounted directly to wooden desks or tables with wood screws. On a metal desk you'll have to drill holes and then use self-tapping screws.

INSTALLING THE TELEPHONE WIRE

The telephone set which has been generally adopted for common battery use is pictured in figure 327. It's called a COMBINED HAND TELEPHONE SET. Ringer, induction coil, condensors, and hookswitch are housed in the base. The transmitter and receiver are contained in the handset. A cradle-

type mounting provides a resting place for the handset when it is not in use.

Figure 327.—Combined hand telephone set.

The combined hand set is as close as you'll come to a complete self-contained telephone instrument. Its installation is as simple as placing it on the desk or table and connecting its output cord to the connecting block. The wires contained in the cord are equipped with terminal lugs for easy installation. Naturally, you'll attach these wires to the same terminals in the block which connect to the inside house wire. And don't forget to mark the assigned phone number on the number card.

There are other types of common battery telephone sets. The WALL SET is similar to the combined set in that all parts, except the transmitter and receiver, are in one box. Of course, it is designed to mount on a wall with a suitable backboard. The center of the transmitter should be $56\frac{1}{2}$ inches from the floor.

The HANGING DESK SET is another type of common-battery telephone. It is composed of three units. There is a BELL BOX, HAND-SET MOUNTING, and HAND-SET. The bell box contains ringer, induction coil, and condensors. The hand-set mounting houses the hook-switch. And the hand-set consists of the transmitter and receiver. You'll place the hand-set mounting and hand-set as shown in figure 328. The bell box

may be located on the wall. However, if the desk is more than 8 inches from the wall, you will have to mount the bell box directly to the desk. The knee-well of the desk is a good spot to place the bell box. An important point to remember about mounting bell boxes is to set the box so that the bell clapper hangs straight down. This will increase ringing efficiency.

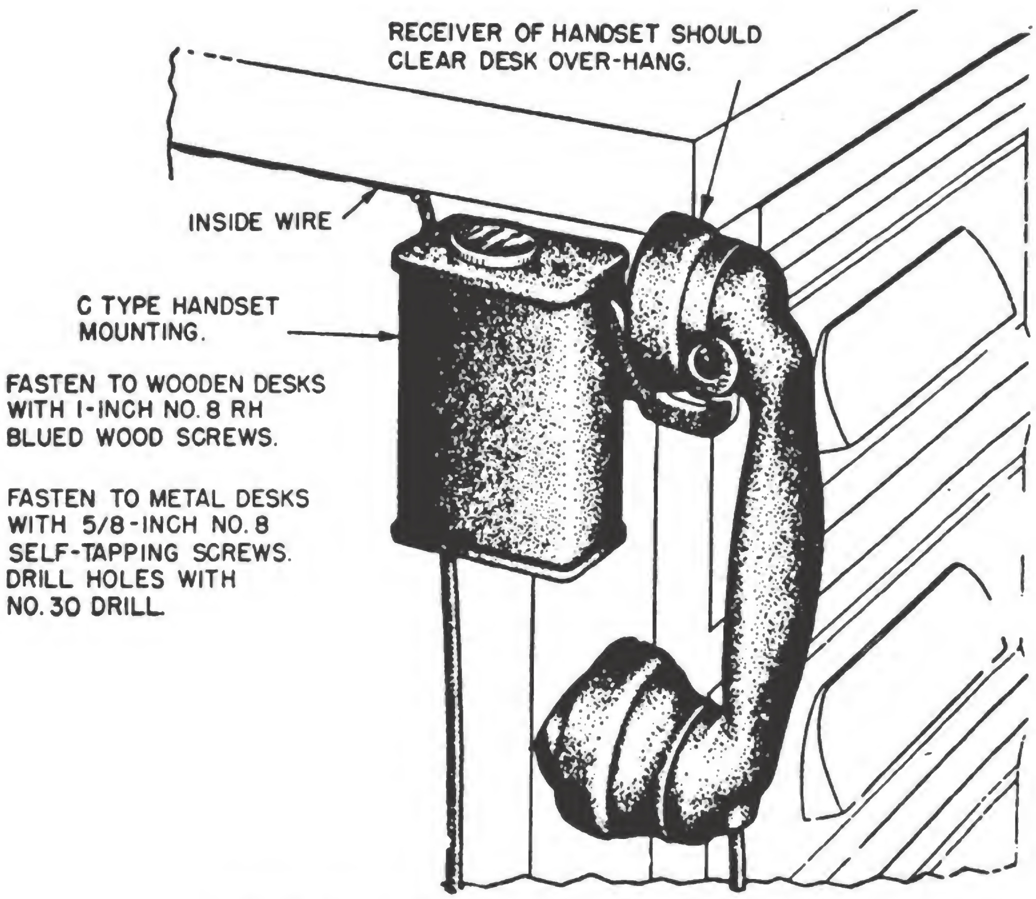


Figure 328.—The hanging desk set mounting.

RINGING OUT

Wait a minute, don't leave yet! Sure, you've got the phone hooked up but how do you know it's connected to the proper line? Remember that the wire chief assigned a number to your installation. He also designated the pair of wires in the outside plant which you were to use. And while you were making the connection, the wire chief wasn't idle. Back at the central

office he attached the designated pair to a jack in the switchboard. Over this jack he placed the assigned number. The switchboard operator is going to plug into the jack when someone calls the number, so the phone had better be on the right line if the call is going to get through.

To find out if your connection is okay, just lift the receiver and contact the switchboard operator. Check to see if the call is coming in on the proper jack. If it is, pat yourself on the back. If it isn't, go out to the pole and connect the inside plant to the correct pair.

It's a good idea to have the switchboard operator ring you back. Then you'll know that the bell circuit is okay. And while you're talking to the operator keep an ear open for the strength and quality of the voice transmission. It should be loud and clear.

TRACER WIRES

Take a look at the drop wire and inside house wire that you used in the inside plant installation. No, not at the conductors themselves, but at the rubber insulation and braid covering. Notice that certain markings or colors are used to distinguish one wire from the other. For example, in parallel drop wire, the rubber insulation of one conductor has a ridge, while the rubber insulation of the other conductor is plain. The conductor with the ridged insulation is known as a TRACER WIRE.

Sometimes the tracer wire is distinguished by a marking in the outer covering. In twisted-pair drop wire it's a raised thread, while one type of inside house wire uses a red thread. And then again, you might find both conductors color-coded—one covered with red rubber insulation, the other with green insulation.

Then you start asking yourself why it's necessary to make a distinction between the two conductors. After all, voice and ringing currents are alternating in nature. And it shouldn't make a bit of difference how the wires are connected. But, hold it. Are voice and ringing currents the only voltages you have on the line? How about a common-battery system where the operating energy is furnished by a battery located

in the central office? You know with that set-up there's always bound to be a d.c. potential on the wires.

Now you're operating on all eight cylinders. The answer to that question you asked yourself is beginning to shape up. Before you can get the complete answer, however, you'll have to be told one more fact. Back at the central office, the positive side of the battery is permanently grounded. This makes the negative line a hot wire. And that provides the key to your question. Because, for purposes of testing and repair, the hot wire (negative) and the ground wire (positive) must be easily identified all the way from the switchboard to the phone. In telephone work the TRACER WIRE is the hot or negative line. If the two wires are color-coded, the RED WIRE is the hot line and the GREEN WIRE the grounded line.

Usually, the hot line is referred to as the RING wire while the ground line is called the TIP wire. They get their names from the contact points on the switchboard plug. The plug has a metal TIP and a metal RING insulated from the tip. Inserting the plug into the jack causes the plug tip to contact the ground wire and the plug ring to contact the hot wire.

Proper Terminal Connections

At the pole you will have to attach the tracer conductor of the drop wire to the RING line and the plain conductor to the TIP line. The pair of binding posts in the terminal box is not marked tip and ring. However, you won't have to guess at it. You see, the cable splicer will always connect the RIGHT HAND binding post to the ring line in the main cable. This is standard procedure. So, when you run the wire for the inside plant, you will use the same plan. That is, at the protective device and the connecting block, the tracer wire will be connected to the RIGHT HAND TERMINALS.

INSTALLING BELLS AND BUZZERS

Bells and buzzers come in handy where there are many telephones at a station working from one or two incoming lines. They permit a central phone location to answer the incoming

calls and then transfer them to the proper party by signaling.

Installing bell and buzzers circuits involves no strain or pain. All you need for a complete circuit is (1) a low voltage source to energize the bell or buzzer, (2) a push button to make and break the circuit, (3) the signalling device (bell or buzzer), and (4) wire to connect the first three components together. The low voltage source may be either dry cells or a bell transformer. A bell transformer will prove the best bet unless, of course, a.c. voltage isn't available.

A look at figure 329 will show you the wiring diagram for a bell circuit. The primary of the bell transformer is connected to the 115-volt lighting circuit. The action of the transformer will reduce the 115 volts to 10 volts at the secondary terminals. The 10 volts is transferred over to the bell by a pair of wires.

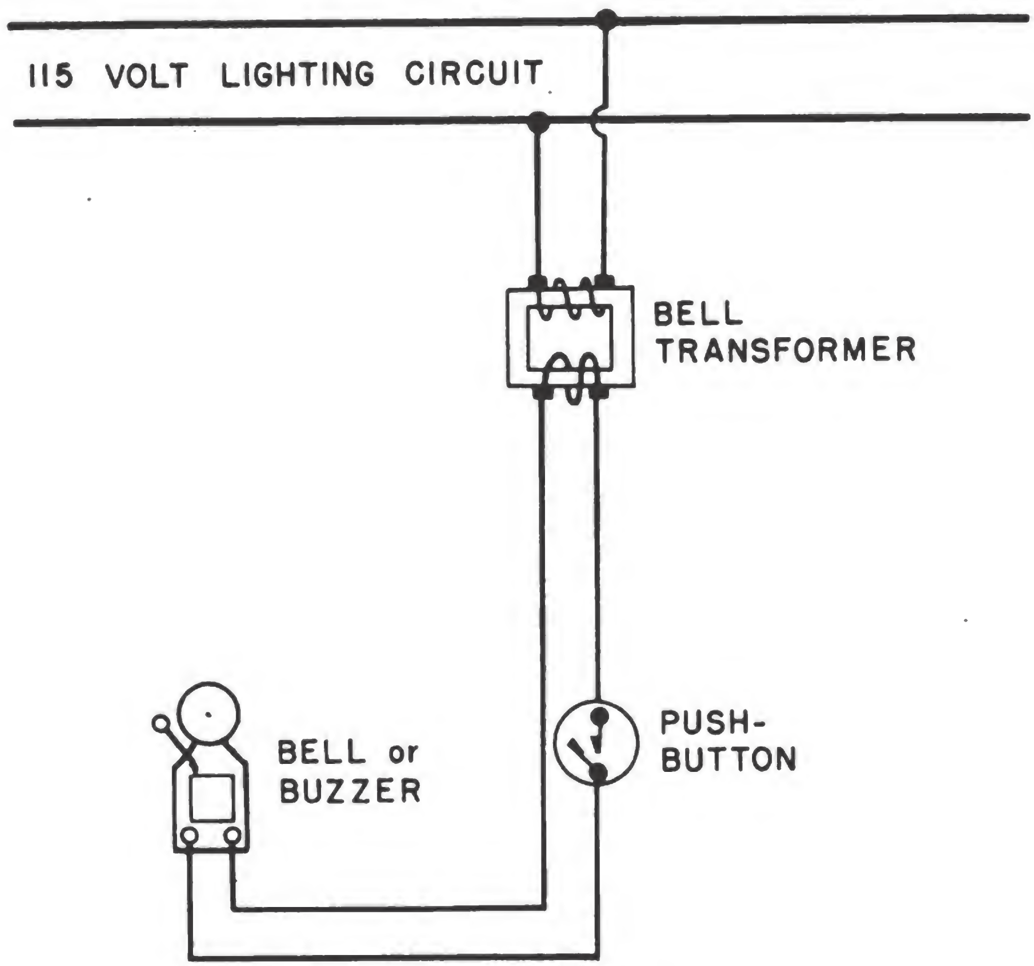


Figure 329.—A bell circuit.

A pushbutton, inserted in one of the lines, controls the current to the bell. Buzzers are sometimes used instead of bells where a loud signal is undesirable. Except for replacing the bell with the buzzer, the circuit of figure 329 will remain the same.

Your first step in installing the bell circuit is to spot the bells, transformer, and push buttons. A BELL will be mounted on the wall at each telephone. The TRANSFORMER will be connected to the lighting circuit at the most convenient point. The PUSH BUTTONS (one for each bell circuit) are placed at the central phone location.

Your next step is to run the wire. The primary side of the transformer is connected to the lighting circuit with no. 14-gage wire. Most bell transformers are equipped with two primary leads, brought out through an end of the transformer case. So, if the transformer can be mounted near a wall outlet, you're in luck. All you have to do is place a male plug on the ends of the primary leads. When the bell circuit is completed, power can be made available by plugging into the outlet.

Bell wire is used to carry the secondary voltage over to the bells. This wire is similar to inside telephone wire except that it is slightly larger—usually no. 18 gage. Because the voltage that it carries is low, the wire can be supported by insulated staples. At the transformer, you will attach the bell wire to the secondary terminals. From there you will train one conductor directly over to the bell, and the other over to the push button. Then it's a matter of running a wire from the push button to the bell. Screw terminals at both bell and push button provide a means of attaching the bell wire.

SUMMARY

The three major parts of a complete telephone system are the central office, the outside plant, and the inside plant.

The drop wire is run from the terminal box on the pole to the protector input.

The subset leads are connected to the connector block.

For open-wire connections, the drop wire is tapped directly to the telephone lines on the crossarm.

Each wire of the telephone pair has a name—ring for the hot or negative line and tip for the ground or positive line.

The ring line is always connected on the right, and the tip is always connected on the left, at terminal posts, connecting blocks, etc.

The drop wire is secured to the pole by means of a drop wire clamp.

S knobs, *C* knobs, screw eyes, bridle rings, and drive rings are types of wire supports.

A porcelain tube is used where the drop wire goes through the building wall.

The inside wire is always run parallel with or at right angles to the building walls.

The combined hand telephone set is the most common type of telephone used.

Wall set telephones are mounted 56½ inches above the floor.

Ringing out determines that you are connected to the proper pair, that the ringer is working satisfactory, and that the voice transmission is loud and clear.

One conductor of the telephone wire pair is termed the tracer wire. This wire is distinguished either by a raised ridge, colored thread, or colored insulation.

When both wires are color-coded, the red wire is the ring and the green wire is the tip.

Bell and buzzer circuits consist of four items: A low voltage source of energy, a push button, a bell or buzzer, and the wire tying these three together.

The voltage of bell and buzzer circuits is approximately 10 volts.

Bell wire is usually #18 gage.

QUIZ

1. What are the three major parts of a complete telephone system?
2. What is the wire called which spans the gap from pole to building?
3. Where does each end of the drop wire terminate?
4. Of how many wires does the drop wire consist?
5. At what two points does the inside house wire terminate?
6. What purpose does the connecting block serve?
7. Where are the drop-wire connections made at the pole when you have open wire?
8. Where are drop-wire connections made when you have aerial cable?
9. Where is the fanning strip found?
10. What is a bridle ring?
11. What is one device that is used to take up the strain of the drop wire between the pole and the building?
12. How many fuses does the protector contain?
13. Name the wires that are attached to the protector?
14. What is the type of hand set most generally used with common-battery systems?
15. How high from the floor should the wall-type set be mounted?
16. When is the bell box for the hanging desk set mounted on the desk?
17. What three things are checked by "ringing out"?
18. What is the conductor called when it has a raised ridge?
19. Which side of the battery is grounded at the central office?
20. What are the two wires of the common-battery telephone circuit called?
21. What are the four component parts of a buzzer system?
22. What size wire is generally used for bell or buzzer circuits?

CHAPTER 15

GROUNDS, SHORTS, AND OPEN CIRCUITS

COMMON TROUBLES

Suppose someone shot this question at you—What three things are common to all normal operating electrical circuits? Okay, you get your thinking machinery to working. Big gears start eating up little gears and out comes a possible answer—wooden poles. After all, both the CEL and CEP use them as supports for conductors. On second thought, though, that's out because the CEG runs his conductors inside of buildings. But wait a minute! You're getting a brainstorm now. Why didn't you think of it before? Part of the correct answer must be CONDUCTORS. Now you're really clicking and it's just a short jump to the complete answer. Because you know that conductors are used for one purpose—to provide a path for VOLTS and AMPERES.

That's it, then—ANY normal operating electrical circuit will

have CONDUCTORS, VOLTS, and AMPERES. But what's it all add up to? Simply this: you'll be working with conductors, volts, and amperes. And with that combination you're bound to run up against SHORTS, GROUNDS, and OPEN CIRCUITS. Any one of which will prevent the volts and amperes from reaching the end of the line. So, it will be up to you to locate these troubles and fix them—whether you're CE, CEG, CEL, or CEP.

TESTING INSTRUMENTS

If you are going to locate and repair grounds, shorts, and open circuits, you must first learn to understand and use common testing instruments. You can feel a shock, or hear a bell ring, but the only way you can "see" electricity flowing in the wire is with a meter.

Take a gander at figure 330. Do these TEST INSTRUMENTS look familiar? Correct, you studied all about them in *Electricity*, NavPers 10622. One whole chapter was devoted to their construction and theory of operation. If you're more than just a little hazy about them, you had better go back and brush up. But if all you need is a little review on their connections, just keep on going.

Voltmeter Connections

The 110-volt single-phase motor starts, but fails to get up enough speed to throw out the starting winding. Perhaps it is low voltage. To find out, take a VOLTMETER, like the one shown in figure 330, and tap it into the circuit. Remember that you're trying to measure a difference in pressure between two points. So touch one voltmeter lead to one of the wires going to the motor. Then touch the second meter lead to the other motor wire. The meter will now register the operating potential between the two motor terminals. Be sure that the meter has been set to record the maximum voltage which could be found between the two points you are checking. Otherwise, you may damage it. And don't forget that if you're measuring d.c. voltages, the polarity of the d.c. voltmeter terminals should match the polarity of the circuit.

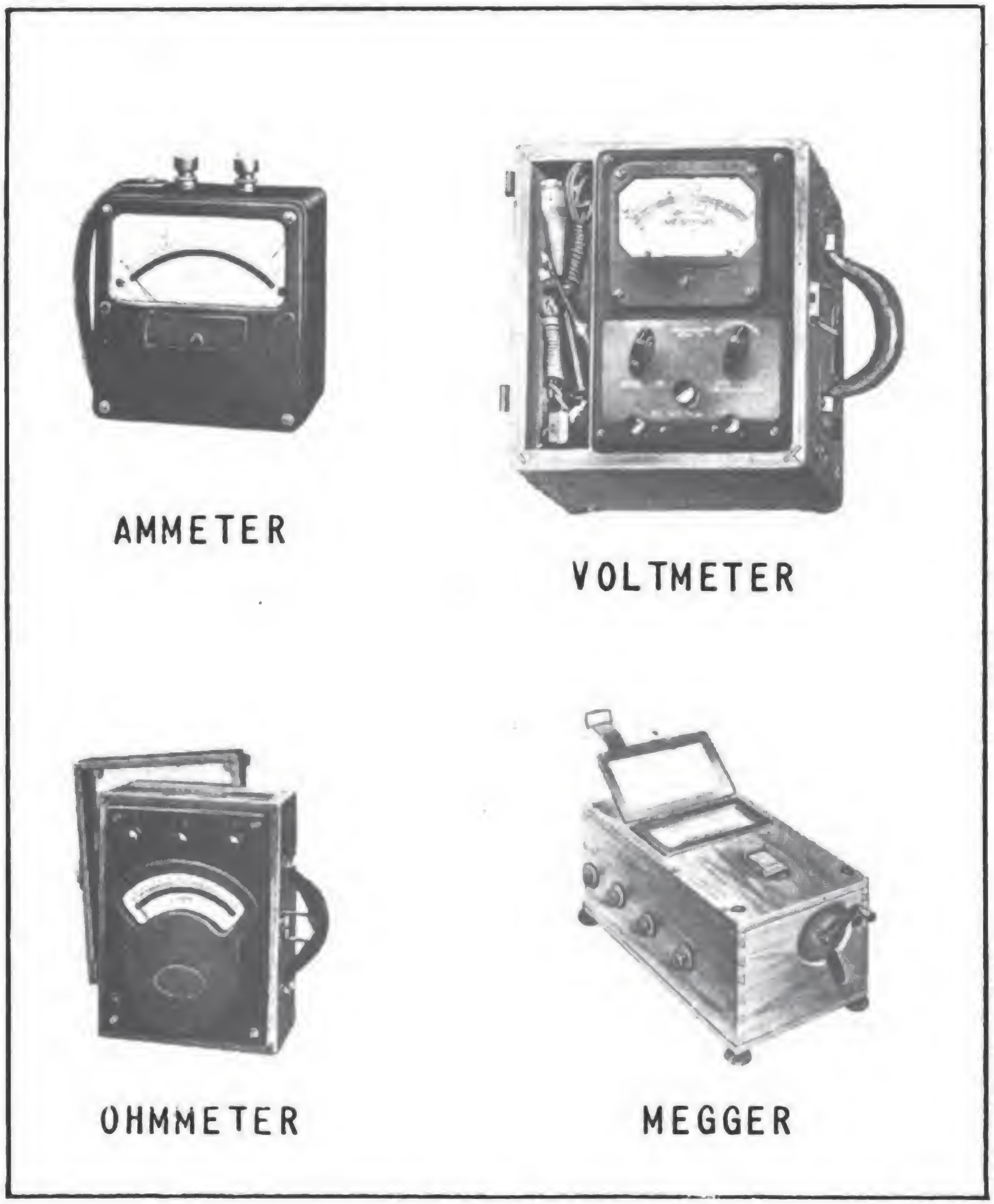


Figure 330.—Test instruments.

Ammeter Connections

After taking the voltage reading you might want to measure the amount of current being drawn by the motor. This is the spot for the AMMETER (figure 330). Of course, it must be inserted in series with the line. To do this, disconnect one motor lead and attach it to a terminal of the ammeter. Run a wire from the other ammeter terminal to the point from which the

motor lead was disconnected. Start the motor and the ammeter will record the current flow in amperes.

Ohmmeter Connections

You're "on the beam" if you know that there are two main types of resistance-measuring meters. One is called an OHMMETER (figure 330), the other a MEGGER. The ohmmeter uses a dry cell for its power supply, while the megger contains a hand-operated generator.

The ohmmeter comes in handy when the resistance of the circuit being measured is not too high. Your first step in operating the ohmmeter is to set it for zero reading. Just touch the two test leads together and adjust the potentiometer. Then place the test leads across the circuit to be measured. The amount of the unknown circuit resistance can be read directly from the meter scale.

When you're checking a circuit whose resistance runs up into millions of ohms you'll use the megger. Suppose you want to find out if the insulation of a field coil in a motor is okay. It's as simple as clamping one test lead to the motor housing, and the other to the bare conductor. This places the wire insulation between the two test leads of the megger. Now use a little elbow grease to crank the megger's generator and take your resistance reading.

Wattmeter Connections

You could use a separate voltmeter and ammeter to find the power output of a generator. The reading of the voltmeter multiplied by the reading of the ammeter will give the power output. But if you use a WATTMETER you won't have to worry about making a mistake in multiplication. Being a combined voltmeter and ammeter, the wattmeter provides a direct power reading.

You'll find four terminal posts on the wattmeter case. One pair of posts is marked "volts," the other pair "amps." The voltage terminals are connected ACROSS the circuit, while the ampere terminals are placed in SERIES.

THE HOOK-ON VOLT-AMMETER

Measure current flow without disconnecting leads and breaking into the circuit? Sounds impossible—but it can be done. And it's so easy, you'll wonder why you didn't think of it.

You know that a magnetic field surrounds any wire which carries current. You know also that the strength of the magnetic field depends on the strength of the current. Now,

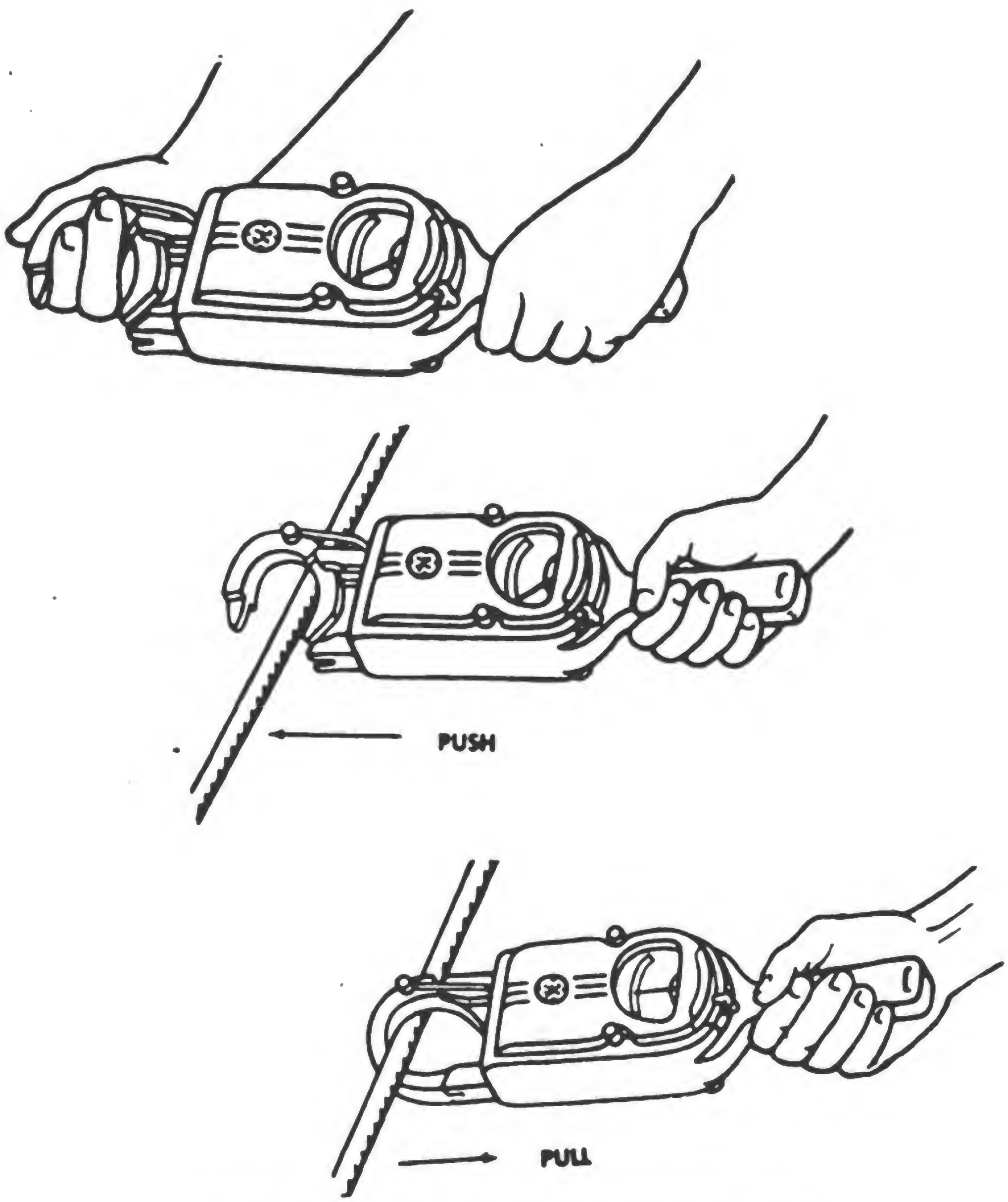


Figure 331.—Operating the hook-on volt-ammeter.

suppose you placed a one turn coil in that magnetic field. If a.c. current flows in the wire, the changing field will cut the coil and produce an induced e.m.f. Connecting the coil to a meter will result in a current flow that can move the meter needle. The meter scale can be calibrated to read directly in amperes. It might make things easier if you think of the wire as the primary and the coil as the secondary of a transformer. The one turn secondary coil and the meter are combined as a single instrument. It's a job called the HOOK-ON VOLT-AMMETER. You can see its construction very clearly in figure 331.

To understand its operation as an ammeter, keep an eye on the three steps in figure 331. In the first step, the C-shaped hook is opened manually. Then the hook is placed against the wire (step 2). A slight push on the meter handle will snap the hook shut. This completes the magnetic circuit for the one turn secondary. After the reading has been taken, a pull on the handle plus the help of a spring will open the hook (step 3).

A selector switch just above the handle provides four current ranges. The lowest setting enables you to measure currents from 1 to 15 amperes. If the current in the conductor is about 1 or 2 amperes, it will be hard to get an accurate reading. You can increase the range, however, by looping the conductor two or three times around the hook. This, in effect, produces a step-down transformer with a resulting increase in current in the meter circuit. You want to be sure and divide the meter reading by the number of conductor loops. This step will bring you back to the true current reading. For example, in view *A* of figure 332, three loops are used. That means you'll divide the meter reading by three.

You can obtain voltage readings, too. There are two terminal posts on the meter case for the connection of test leads. You'll use it just as you would an ordinary voltmeter. The selector switch enables you to convert the meter from ammeter to voltmeter. View *B* of figure 332 shows you how to secure both current and voltage readings.

SHORTS IN INTERIOR WIRING

The fuse blows. It's replaced with another and "wham!"

it blows, too. Someone finally decides there's something wrong, and a call goes out for a CEG—and you're it. If you're "on the ball," you'll realize that a SHORT is causing all the trouble. Sure, it might be an overload, but usually the fuse heats up slowly and then burns out. When they blow out as fast as you put them in, it's almost always caused by a dead short. Somewhere in the system the current is flowing between black and white wire without sufficient resistance.

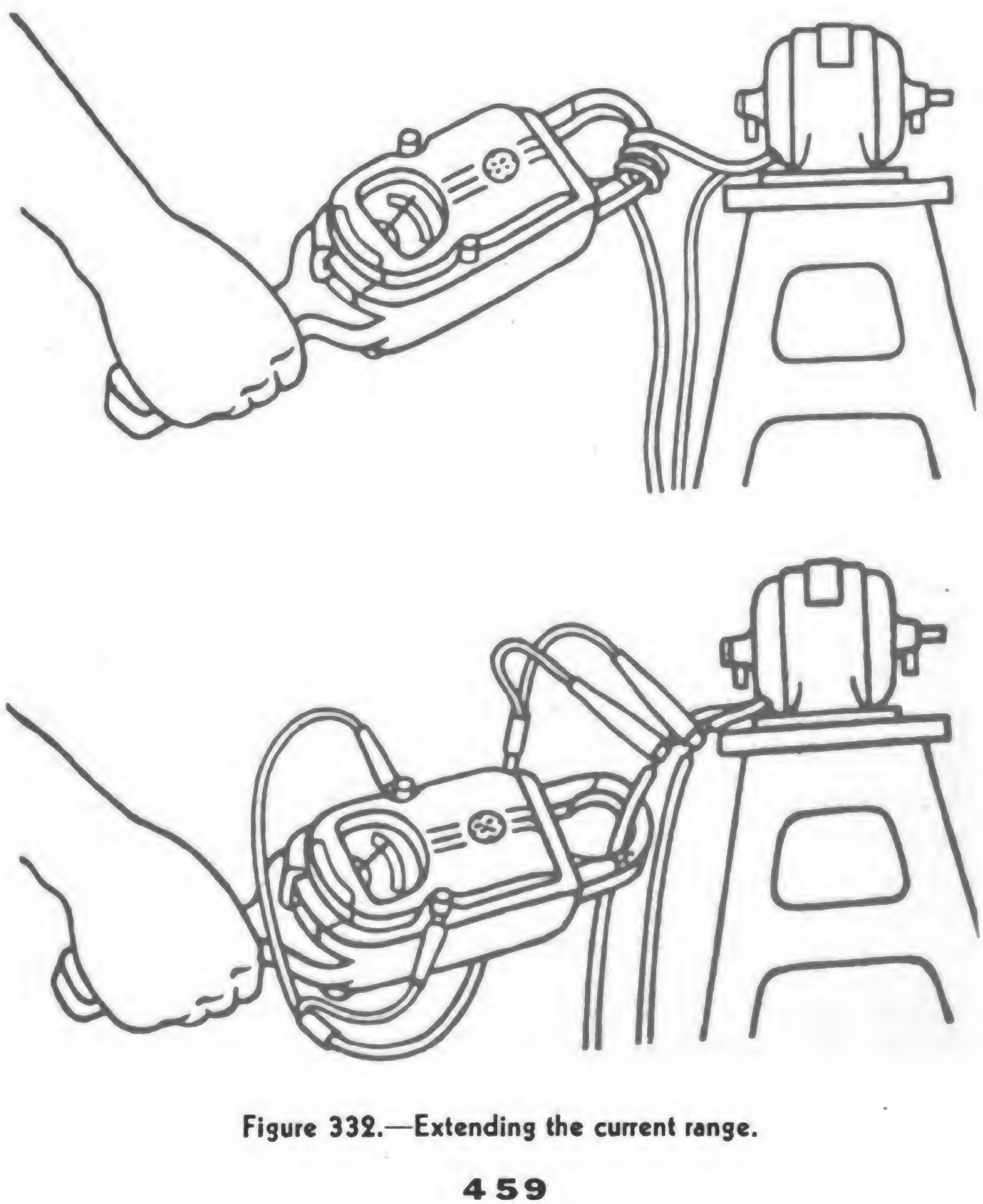


Figure 332.—Extending the current range.

Since the fuse blew, you have automatically eliminated all the circuits in the building except the one which the fuse serves. The first thing you'll want to do then, is make a quick visual check of this circuit. About half the time the short will be readily apparent. Someone moved a piece of equipment against the line—a spark has been jumping from a box—or something started smoking just before the fuse blew. But this isn't your lucky day. You examine the equipment and question the personnel but fail to find any apparent source for the short. It looks like you'll just have to dig into the circuit and locate the trouble for yourself.

It's a good idea, of course, to have some general plan before you start to dig. In other words, just how will you go about locating the short? To begin with, you know that the branch circuit consists of two wires—one black (hot) and one white (ground). They start at the panelboard and end up at the equipment. Now, normally, the current which flows between the black and white wire will first go through the equipment. However, at some point in the circuit, the current has found a short cut. What you will have to do, then, is disconnect the wires systematically until the short circuit current is cut off. And you'll use a TEST LAMP as a helper.

The Test Lamp

The test lamp is merely two light bulb sockets wired in series (figure 333). A 110 volt light bulb is screwed into each socket. For the current to flow, it must pass through BOTH bulbs. Thus, when placed in a 110-volt circuit the bulbs burn, but not with full brilliancy. But when placed in a 220-volt circuit the bulbs burn normally. So, with this device you may determine two different voltage ranges and whether current is flowing in the circuit.

Locating the Short

Now, back to your short. Go to the panelboard and disconnect both the white wire and the black wire from the source of supply. Current can now go only as far as the fuse, which you may safely replace. Touch one test lamp lead to the FUSE

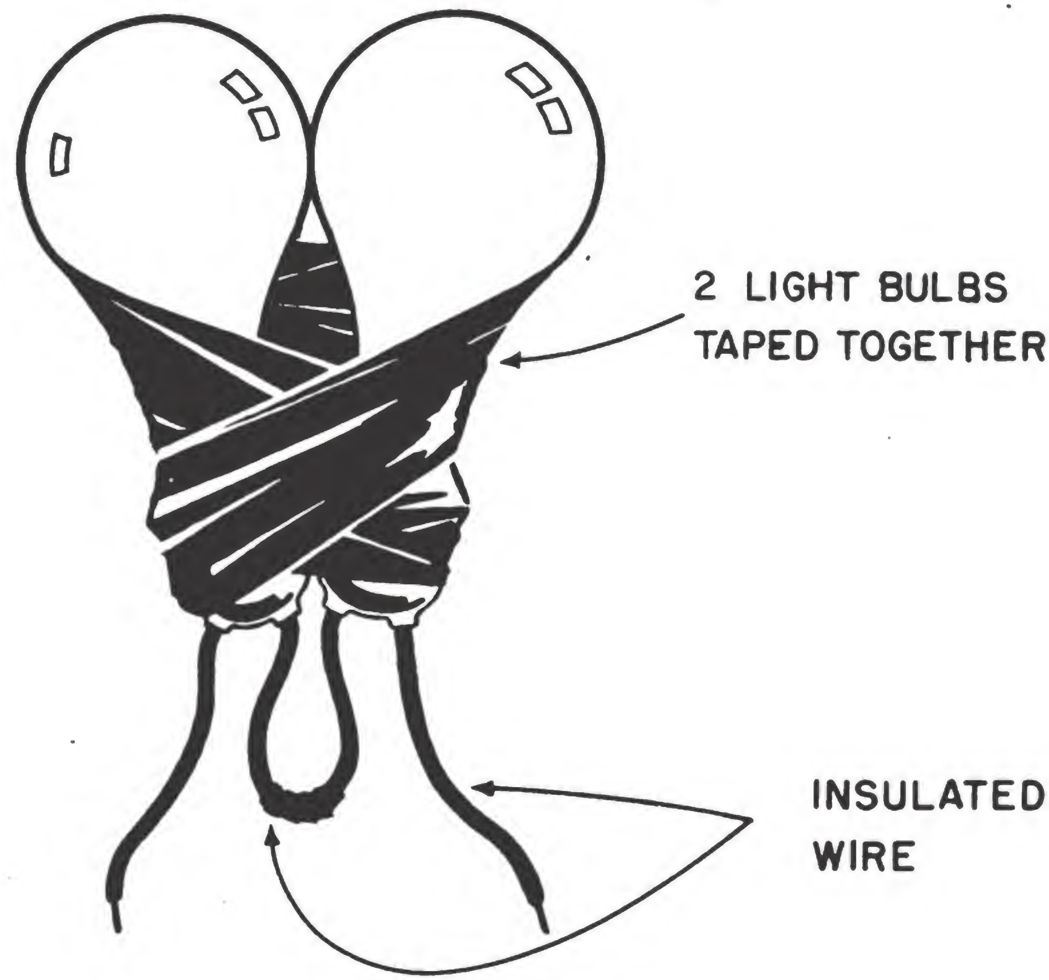


Figure 333.—A test lamp.

BLOCK and the other to the BLACK WIRE. If the lamp doesn't burn you know definitely that the trouble is a short and not a ground. If it were a ground the bulbs would light, because the current could still travel through the bulbs into the black wire, and into the ground at the defective spot. And from there it could flow back through the water pipe ground wire to the panelboard. Since there is no ground, you may safely reconnect the black wire without blowing another fuse.

Now touch your test lamp leads to the GROUND TERMINAL and the WHITE WIRE. The bulbs will light, indicating a definite short. Stop this flow of current and you will have eliminated the trouble. First, turn off all switches in the circuit, and pull all plugs from receptacles. Now check again at the panelboard and see if the test lamp lights. If it doesn't, your short is in a

fixture or a piece of the equipment. You may locate it easily by turning them back on, one by one. However, if the light still burns, it is almost certain that the short is in one of the junction boxes. Sure, it could be within the conduit itself, but this hardly ever happens. So, that will be the last thing to check.

Before you start to check your junction boxes, here are a few words of warning: ALWAYS REMOVE THE FUSE TO "KILL" THE CIRCUIT BEFORE DISCONNECTING OR CONNECTING WIRES. Now you're ready to go. Start at the middle box in the defective circuit. Disconnect the wires and, after replacing the fuse, check with your test lamp between the white wire and the ground terminal at the panelboard. About two more check points and you will have it eliminated down to one box. At that point you will probably find that whoever wired the building did a very poor job of taping the wires.

GROUNDS IN INTERIOR WIRING

Suppose you discovered a ground in the circuit when you disconnected the wires at the panelboard. You wouldn't let it throw you, because the procedure for locating a ground is the same as for a short. The test lamp is placed between the fuse block and the black wire. Again it's a matter of reducing the circuit into smaller and smaller sections until the trouble is pin-pointed.

OPEN CIRCUITS IN INTERIOR WIRING

An open circuit means a break in the line. The current is not getting to the point where it is needed. This is the easiest of all troubles to locate. You just pick up your test lamp and start checking all points, beginning at the center of the circuit. If the lamp burns, the circuit is good that far. In about two minutes you can determine where the fault lies. And usually you will find that the installation mechanic failed to solder a wire connection properly.

POINTERS ON DEFECTIVE EQUIPMENT

Quite a large number of your service calls will be the result

of defective equipment. They may have shorts, grounds, open circuits, or maybe they just don't work right. Motors get hot, elements burn out, belts break, and starters won't start.

The test lamp again will prove to be a handy tool. But here you will also find use for the voltmeter, ammeter, and ohmmeter. Generally, if the equipment doesn't work, you can find the trouble with the test lamp. However, if it works, but doesn't do so properly, you will need your meters. With them it is a simple matter to check the rated voltage, amperage, and resistance against the actual values.

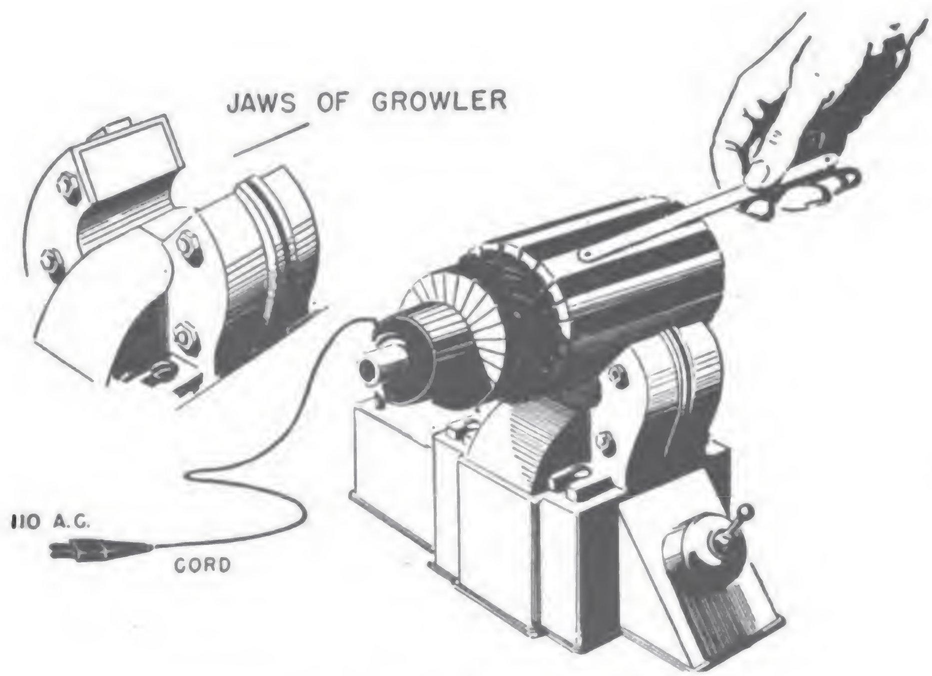


Figure 334.—Armature testing with a "growler".

MOTOR TROUBLES

The motor is "dead"! Yes, it most likely has a short, ground, or open circuit. Sure, there are many other things which could easily be causing the trouble, but 9 times out of 10 they are defects which are readily apparent and require no testing to locate. You don't need a microscope to determine that the bearings are burnt out when the shaft "freezes" and you can't turn the motor over by hand. Nor would you yank the motor

off the block and rush it to the shop for repairs if the line is dead and the motor isn't getting any "juice."

Have you looked at figure 334? This is one of the commonly used motor testers. It gets its name "growler" from the hum it makes when you place an armature on the jaws. When you turn on the "growler" it produces a changing magnetic field that cuts the armature coils. A voltage and current is induced in the coils, which in turn magnetizes the laminated armature core. The presence of smoke immediately indicates faulty insulation at that point in the armature winding. If there is no smoke, place a hack-saw blade on the coil as shown in figure 334. Now rotate the armature. Once you strike a spot that has a short, the blade will be attracted to the coil. This attraction for the hack-saw blade is quite noticeable. And after using the "growler" several times, you will experience no trouble in distinguishing it.

GENERATOR PLANT TROUBLES

The generating equipment which you studied in chapter 7 is going to give you very little trouble on the generator end. That is, providing you keep the equipment in good condition. Most of your headaches will come from the prime mover. If trouble does develop, it will very likely be apparent on the generator gages, or it would be a noise which you would hear. A few of the troubles which you might encounter are listed here as a guide:

No voltage? Check the following:

1. Voltmeter defective.
2. Dirt or bad brushes on the exciter armature or collector rings.
3. An open in the exciter shunt field.
4. A short in the alternator shunt field or the exciter armature.

Low voltage? Check these:

1. Engine running too slow.

2. Improper setting of the exciter rheostat.
3. Dirt around the commutator or collector rings.
4. Voltage regulator defective.
5. Short or ground in the alternator shunt field, the exciter armature, or the alternator stator winding.

When the generator overheats check for:

1. Shorted or grounded stator or rotor coils.
2. Worn out bearings.
3. Poor ventilation.
4. Overload.

If the exciter overheats look for:

1. Short or ground in alternator or exciter shunt field.
2. Bad bearings.
3. Poor ventilation.

Noise is probably caused by:

1. Bad bearings.
2. No lubrication.
3. Overload.
4. Wrong connections to alternator.
5. Alternator stator has short or ground.

When you are assigned to a permanent generator plant installation, you will find that preventive maintenance will almost entirely eliminate "trouble shooting." Breakdowns are held to a minimum by maintaining a constant generator watch, keeping a log on the equipment's operation, and periodic shutdown of the generator for overhaul, cleaning, and checking. The length of the shutdown is determined by the number of hours the machine has operated. For example, there is the 100-hour check-up, the 200-hour check-up, and finally, the major overhaul after a definite period of operation as specified by the manufacturer or your officer. There is no disruption of service during these shutdowns, for the plant will have at least one extra generator.

OVERHEAD DISTRIBUTION

The storm came, the wind blew, and now comes the lineman's headaches. Wires are down, service is out, and half the base is hollering for electricity. But wait a minute! These are high voltage "hot" lines. You don't go dashing out with your climbers and start stringing new wire. All this requires special tools, special techniques, and it must be done under the strict supervision of the chief. The maintenance and repair which you will perform will consist of that type of work covered in chapters 8, 9, and 10. Among other things, this would include stringing new wires and replacing insulators, cross arms, and poles on "dead" lines.

TELEPHONE PREVENTIVE MAINTENANCE

You have fixed the short in the terminal box, and before you leave you are going to inspect for PREVENTIVE MAINTENANCE. You check for defective face plate, broken lugs, dust, and dirt. Drop wire connections are inspected and you tighten all unused pairs finger tight. You check the drop wire attachments, redress corroded wires, and brush off the face plate with a terminal brush. Finished? Wait a minute! While you're at the pole, check that drop wire going over to the building. Make sure its insulation isn't damaged and that it is properly strung and securely supported. See that limbs or other wires do not interfere with it.

When making repairs to a subset you also perform preventive maintenance. Check the protector. Is its location such that it is protected against damage or moisture? Are the fuses okay? Be sure they are not broken, defective, or loose, and that they are tight in the mounting. Clean the carbon blocks and replace them if they are broken or badly pitted. Check the protector cap and screw it on tightly. Check the ground wire.

You should also inspect the line from the protector to the subset. The insulation may be damaged and it may not be surely fastened or have an adquate clearance from other wires.

If there is a connecting block, check the connections and be sure the cover isn't bent so that it touches the terminals.

At the subset examine the transmitter for cracks or breaks in the mouthpiece. See that its connections are tight, no rim screws missing, contact springs properly secured, and that there is no dirt or moisture in it. Check the receiver for cracks and make sure there is no dirt, moisture, or corrosion inside or on its diaphragm. Inspect the capacitor and see that the leads are properly soldered. How about the ringer? Is it securely mounted, with no nicks, dents, or cracks on the coils? Perhaps the gongs are loose or there are metal filings around the armature. Always check the hook-switch for rusty, bent, or pitted springs. Observe the hook-switches' contact and lever action, and see that the stay cords and hooks are secure.

TELEPHONE CORRECTIVE MAINTENANCE

Grounds, shorts, and open circuits will take up most of your corrective maintenance time. These troubles may be indicated at the switchboard or at the substation. But in either case, it's the wire chief at the central office who will receive the complaints. He will make the tests necessary to determine the nature and general location of the trouble. He'll give you the pair number, the telephone number, the location of the subset, and, if necessary, the location of the terminal boxes. Then, it's up to you to go out and do some fixin'.

But "hold the phone!" Are you sure you're straight on all the facts about the common battery system? If not, maybe a little review list will help.

1. Voltage is furnished by the central office battery to each pair in the outside plant.
2. This voltage is always available on a pair at any point between the subset and the central office.
3. Each pair is composed of a TIP and RING line. The ring line is the "hot" line, while the tip line is grounded.

THE TEST PHONE

Naturally, you'll need some sort of test instrument to help you locate the trouble. The TEST TELEPHONE shown in figure

335 will do a good job for you. It is simply a telephone handset with cable clamps on the ends of its two test leads. Whenever a momentary current flows through the receiver a "click" will be heard. So, you see, the test phone will indicate the presence or absence of current in a telephone circuit.

Figure 335.—Test telephone.

TELEPHONE LINE OPENS

The wire chief receives a complaint on an open in one of the pairs. He turns all the information over to you, and off you go with your trusty test phone. Your first stop is the closest terminal box to the central office. Of course, it will be a box which has terminals tapped into the pair you are testing.

At the box you connect the test phone leads across the proper terminals. One test phone lead is clamped on, the other is tapped against the terminal. If a sharp click is heard at each tap you know that battery voltage is present up to that point. This means a good line as far as you have gone. So you travel over to the next terminal box.

This is the terminal box to which the drop wire is connected. You check with the test phones and receive a click. Everything's okay up to this point, too. So the open must be somewhere

in the drop wire or inside house wire. The protector is a dividing point between these wires, so that's where you'll head for. When you place the test phones across the protectors no click is heard. The open must be in the drop wire. Perhaps a visual inspection will locate the trouble and you can splice the wire. If not, you will have to replace the whole drop wire.

Suppose you failed to receive a click at the pole. It would mean that one line is dead in the aerial cable. Now check to find out which one. You tap from ring to ground. A faint click doesn't mean a thing. It is just due to slight differences in ground potential. The click must be sharp and definite. You can't secure a sharp click so you know it is the ring line which is open. Report this information to the wire chief and he will assign you another pair to use. Tap the drop wire into the newly assigned pair's terminals and test. No, you won't be the one to fix the open in the aerial cable. That calls for a man with several years of cable splicing experience. The wire chief will take care of it. Be sure you make your preventive maintenance check before you shove off.

CHECKING THE GROUND WIRE

In making your preventive maintenance check, you may also use your test telephone to determine if your ground line at the protector has an open. Your pair comes into the protector. Attaching one test telephone lead to the ring line and tapping the tip line with the other test lead produces a click. Now, instead of tapping the tip conductor, tap the ground terminal. If the circuit is good to ground, you will receive a definite click. The absence of a click indicates an open in the ground wire.

TELEPHONE LINE SHORTS

To locate a line short you'll still have to use your test receiver. Look at figure 336. There is a short in the line between the two test points. This short causes the signal lamp on the switchboard to burn continuously. You place your test receiver in SERIES with the tip line at the first check point. A click tells

you that you are between the short and the central office. So keep working along the drop line towards the subset until you fail to receive a click. Then you know you are beyond the short. It is some place between the last point where you received the click and the first place that you failed to receive the click. A visual inspection will probably locate the short if it is in the drop wire, and you can make the necessary repairs. However, if the short is in the aerial cable you will ask the wire chief to assign you a new pair and leave the removal of the short in the old pair up to him.

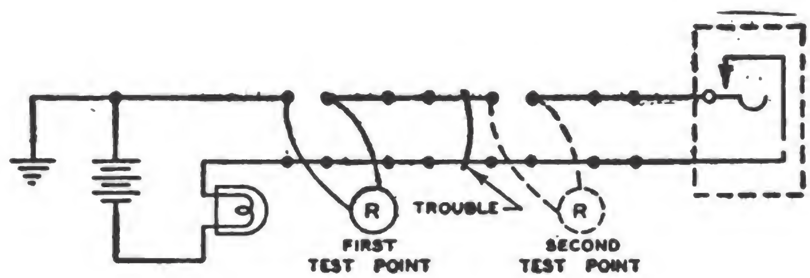


Figure 336.—Testing for line shorts.

TELEPHONE LINE GROUNDS

When you ring line "grounds out" the signal lamp at the switchboard is going to light up continuously. Grounding of the tip line would cause the circuit to be noisy, due to ground returns of other currents. Grounding of both lines would completely disrupt service and the signal lamp would burn continuously.

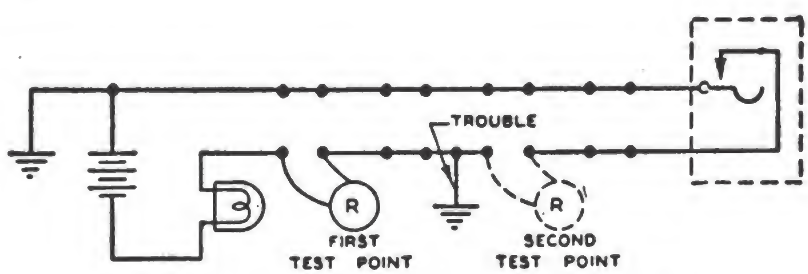


Figure 337.—Testing ring line for a ground.

Having two lines to check, suppose you check the ring line first. Just as shown in figure 337, you place your receiver in

SERIES with the ring conductor at the terminal box on the pole, and you receive a click. The current flows from the central office battery, through your test receiver, into the ground at the defective spot, and back to the battery. Keep checking towards the subset until you fail to receive a click. You are then beyond the ground.

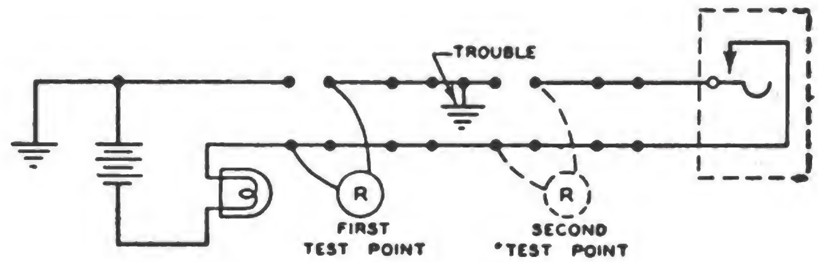


Figure 338.—Testing for a tip ground.

When the ground is in the tip line, you check as shown in figure 338. Attach your test receiver leads to the ring line and the tip line at the pole. However, you must disconnect the tip line from its terminal and use the tip line leading TOWARDS the subset. Normally no current should be able to flow through your test receiver as long as the phone is on its hook. But, a click indicates that a ground is present, and that it is between you and the subset. Keep checking until you reach a point at which you fail to receive a click. The ground is between the last two places tested.

OTHER TELEPHONE TROUBLES

There are many things which can happen to a 202-pair cable to disrupt the service. Mix-ups between pairs are called crosses. They could consist of most any combination of grounds, shorts, and opens. They may be tip to tip, ring to ring, ring to tip, or several combinations of these, depending on how many pairs were involved in the cross.

The elimination of crosses is not too difficult when considered on the basis of correcting one pair at a time. Remember that a pair consists of a "hot" line and a "ground" line. And disconnecting this pair should immediately "kill" it, and eliminate the ground. If either wire of the pair is still hot or grounded,

you must disconnect or test the other pairs until you discover the pair which is causing the trouble. The receiver must be "hung up" so that the hook-switch will be OPEN while conducting these tests.

SUBSET TROUBLES

The wire chief gives you a service call and tells you the location, telephone number, and type of instrument. You pick up a similar subset and take off.

The first thing to do when checking the subset is to verify the trouble. Many times you will find that there is just a loose connection, iron filings around the ringer magnet, or some other easily located trouble. And frequently, you will find that there isn't a thing in the world wrong with the set except the fellow who is trying to use it. So be sure to test the phone for yourself before starting to tear it apart.

Remember all that preventive maintenance check for the subset which you studied in the first part of this telephone section? That is the extent of your servicing on the job. Sure, you can replace the condenser without replacing the subset. But it takes 2 minutes to replace the subset and 20 minutes to replace the condenser. The idea is to get the telephone circuit back into operation immediately. Then take the old set back to the shop where you have all the various parts, test equipment, and soldering irons necessary to repair it. In that way, a complete and thorough check may be made without interfering with other people's work or cluttering up their offices.

Checking the Subset

You have the subset back in the shop and have already made your preventive maintenance check. Now, since the instrument is disconnected, you will have to furnish your own source of power to test each of its component parts. Hook up a battery in SERIES with your test receiver. Each part is then tested in SERIES with your tester.

The receiver and transmitter are both tested in the same manner. Attach one test phone lead to a receiver or transmitter terminal. Tap the other test lead against the other terminal.

A click indicates a good instrument. No click would be an open. A real sharp click when testing the transmitter indicates that it is packed (shorted).

Place your test leads against the capacitor's two terminals. Tap several times. You should receive a click—but only ONE. No clicks indicate an open capacitor, while more than one shows that the capacitor is shorted. Reverse your leads and you should immediately receive a click—but only ONE, even though you tap the capacitor repeatedly.

Check the ringer assembly by connecting it to a ringing current. The clapper should move freely and the gong should produce a clear tone. Test the ringer coil by attaching your test leads to the coil leads. Sharp click—shorted coil; no click—an open; normal click—coil is okay. The induction coil is tested in the same manner, clicks and all. However, be sure that you test each winding independently.

THAT'S ALL

This is the last page of the last chapter, and you've come a mighty long way. So just sit back, relax, and give a little thought to what you've accomplished. First of all, you know darn well that there's still a lot more to learn. You'll run across a thousand and one situations in the field which could not possibly be included in this manual. And second, you're not foolish enough to believe that just reading this manual makes you a five-star electrician. You're going to need a lot of actual practice, too. What counts, though, is that you have studied the basic principles of your work. And, in the process, have acquired the language of the CE. So from now on, it's up to you. Keep your eyes and ears open, listen to the chief and first class, and when in doubt—ASK QUESTIONS.

SUMMARY

A hook-on-volt-ammeter measures current flow by the induction principle.

A short in an interior wiring system provides a bypass for the current before it reaches the equipment.

A test lamp can be used to determine two different voltage ranges and whether current is flowing in a circuit.

Always remove the fuse to "kill" the circuit before disconnecting or connecting wires.

A "growler" is a common motor tester and works on the induction principle.

When using a "growler," attraction between the hack-saw blade and the armature core indicates trouble.

The test telephone is used to indicate the absence or presence of current in a telephone circuit.

QUIZ

1. What is an important point to remember when checking voltages with a d. c. voltmeter?
2. How must an ammeter be connected in the circuit?
3. What is the power source of a megger?
4. How may the current range of the hook-on-volt-ammeter be increased?
5. What action does a fuse follow when an overload develops in an interior wiring system?
6. What is the first step in testing a defective branch circuit?
7. What voltage will cause the test lamp to burn with normal brilliancy?
8. What type of trouble is indicated if the test lamp burns when placed between fuse block and black wire while the white wire is disconnected?
9. What safety precaution must always be observed before disconnecting wires?
10. Where is the most logical starting point for testing a defective circuit?
11. What does the presence of smoke indicate in an armature under "growler" test?
12. What would be the effect of an open exciter shunt field in an alternator?
13. Name one common test instrument used to locate troubles in telephone circuits.
14. How does the test telephone indicate the presence of current in a circuit?
15. If the ring line grounds out, what will happen to the signal lamp at the switchboard?
16. When a telephone receiver is "hung up," is the hook-switch circuit open or closed?
17. What is the test telephone's indication of an open capacitor?

APPENDIX I

ANSWERS TO QUIZZES

CHAPTER 1

GETTING ACQUAINTED

1. (a) CE—Construction Electrician. All phases of electrical construction.
   (b) CEG—Construction Electrician, General. Interior wiring and shop work.
   (c) CEP—Construction Electrician, Power. Generating and power distribution.
   (d) CEL—Construction Electrician, Line. Communications installation and maintenance.
2. The chart showing the practical factors and examination subjects requirements for each rate and rating.
3. *General Training Course for Non-rated Men* and *General Training Course for PO 3 & 2.*
4. 1. *General Training Course for Non-rated Men.*
   2. *General Training Course for Petty Officers.*
   3. *Mathematics.*
   4. *Electricity.*
   5. *Use of Tools.*
   6. *Use of Blueprints.*
   7. *Basic Machines.*
5. Your educational office.
6. To help you to use your brain instead of your brawn in many of the situations which you will encounter in the field.
7. A circuit which has only one path from source through the loads and back to source.
8. A circuit which has more than one path from source through the loads and back to source.

CHAPTER 2

WORKING WITH CONDUCTORS

1. A wire or group of wires not insulated from each other.
2. Copper.
3. Wire and cable. A wire is a single, solid conductor. A cable is two or more conductors grouped or twisted together within a single protective covering.

4. Rubber, varnished cambric (varnished cotton cloth), asbestos, paper, silk, enamel.
5. Fibrous braid, metallic armor, and lead sheath.
6. American Wire Gage.
7. No. 4.
8. Just as strong as the wire or cable that is being spliced.
9. A coating of tin or tin alloy.
10. Western Union, duplex, rat-tail joint, fixture joint, and wrapped splice.
11. The joining of a conductor to another conductor, one or both of which are a continuous wire.
12. The applying of a thin coating of solder to the complete area or surface that you wish to solder.
13. Blowtorch (gasoline), alchohol torch, and soldering irons.
14. Rubber and friction.
15. One which joins two wires firmly together by applying a mechanical pressure against them.

CHAPTER 3
BATTERIES

1. Two unlike electrodes in a chemical solution.
2. Two or more cells connected together.
3. The type of electrodes used.
4. Small, light, and portable.
5. It will produce a high current for a considerable period of time.
6. A carbon rod, a zinc container, and a moist paste of ammonium chloride.
7. Plates of lead, plates of lead peroxide, and a solution of sulphuric acid.
8. Series connected.
9. Parallel connected.
10. Open circuit and terminal voltage.
11. The terminal voltage.
12. 20 hours (100 ampere-hours).
13. The weight of a substance compared to the weight of an equal volume of water.
14. 1.000.
15. 1.280 to 1.300.
16. Due to the burns you can receive from it and the fact that it will attack almost everything except glass, earthenware, and lead.

17. To determine the specific gravity of the electrolyte.
18. Vaseline or grease.
19. With a solution of baking soda and water.
20. 1200 to 1225.
21. 1.75 volts.
22. That the charging rate is excessive.
23. When three successive half-hour checks show no rise in specific gravity readings.
24. Constant current and constant voltage.
25. Stored in a jar of distilled water.

CHAPTER 4

DIRECT CURRENT MACHINES

1. Horsepower.
2. Watts.
3. The electrical circuit and the magnetic circuit.
4. Sleeve and ball bearing.
5. Field coils, armature windings, commutator, and brushes.
6. It would heat up and lose its spring tension.
7. Series, shunt, and compound.
8. High starting torque.
9. Its speed varies as the load changes.
10. Compound.
11. Don't use emery cloth and don't use gasoline or lubricants.
12. Sandpaper.
13. No. 10 weight, 2110.
14. Grease.
15. Carbon tetrachloride.
16. To prevent them from becoming insulated.
17. To prevent corrosion and to keep them free of dirt and trash.
18. The manufacturer's instruction book.

CHAPTER 5

ALTERNATING CURRENT GENERATORS

1. Alternator.
2. The transformer.

3. On small alternators the armature coils revolve and the field coils are stationary. On large alternators the armature is stationary and the field coils revolve.
4. Two.
5. Exciter.
6. Prime mover.
7. By adjusting the speed of the prime mover.
8. By changing the setting of the exciter field rheostat.
9. Keep insulation clean and dry; keep electrical connections tight; and keep machine in good mechanical condition.
10. The manufacturer's instruction book.

CHAPTER 6

ALTERNATING CURRENT MOTORS

1. The secondary.
2. No; it is induced.
3. Follows.
4. Squirrel cage rotor.
5. The laminated steel offers a high resistance to the flow of a.c. current in comparison to the copper bar assembly.
6. 75-80 percent.
7. A capacitor motor.
8. Centrifugal force.
9. Universal motor.
10. Across-the-line-starters and reduced-voltage starters.
11. Manual and magnetic.
12. To prevent a sudden drop of line voltage which would interfere with the operation of other equipment in the circuit.

CHAPTER 7

ADVANCED BASE ELECTRIC GENERATING STATIONS

1. Requires less personnel; no auxiliary power available in case of breakdown; and provides protection from the weather.
2. Exhaust, inlet or intake, compression, and power.
3. Oil and metal wool.
4. The pipe is extremely hot and you might receive a severe burn.
5. To prevent water from flowing through the radiator until the motor reaches normal operating temperatures.

6. The injector.
7. 200 mesh.
8. To prevent condensation.
9. They are built lighter than Diesels.
10. Battery, ignition switch, ignition coil, distributor, and spark plugs.
11. The outer electrode.
12. Crocus cloth.
13. Just as the lamps are going out.
14. Just before the meter's hand reaches dead center.
15. By increasing its speed.

CHAPTER 8

DISTRIBUTING ELECTRIC POWER

1. Feeders.
2. Primary mains.
3. Secondary mains.
4. Delta and *Y*
5. 2,300 volts.
6. The primary.
7. None.
8. To give a greater area for the dissipation of heat.
9. Oil.
10. Yes.
11. The primary.
12. In open delta (or V).
13. In case one burns out the remaining two may be connected to open delta and still furnish 57.7 percent of the original capacity.
14. At the center point.

CHAPTER 9

POWER-LINE CONSTRUCTION

1. The butt end.
2. The roof.
3. Gains.
4. The face.
5. Creosote oil.
6. It is toxic and will blister the skin.

7. Pike poles and deadman (or mule).
8. Lift the pole.
9. Cant hooks.
10. The rings on either side of the tool belt to which the safety strap is attached.
11. Saddle soap and neat's-foot oil.
12. With a block and tackle.
13. Guy wire.
14. Cone, plank, and screw anchors.

CHAPTER 10

STRINGING THE POWER LINE

1. Reel out the wires, raise the wire to the crossarm, tension the wires, and tie the wires in.
2. No.
3. Soft-drawn.
4. The dip of the wire between poles.
5. Oscillation, dynamometer, and sighting.
6. A vertical rack that contains the insulators to which the secondary mains are secured.
7. Hoist and attach the transformer to the pole; connect the primary main to transformer primary through fuses; install lightning arresters on primary side of transformer; and connect jumpers from transformer secondary to secondary mains.
8. Fuses and lightning arresters.
9. The lightning arrester.
10. To present a high resistance to the passage of the normal line current.
11. In series between the transformer and the primary main.
12. 8 feet.
13. 6 inches below the surface of the ground.
14. The service leads.
15. By means of a toggle bolt.
16. Artificial respiration.

CHAPTER 11

INTERIOR WIRING

1. The general location of all items in the building, and the specifications as to types and quantities of material to be used.

2. The service leads, and the service switch or main switch.
3. Series.
4. In order to have one conductor which is at a neutral or ground potential.
5. Provides a distribution center; fuses the circuits; and provides switches that may be used to "kill" the circuits individually.
6. No. 12 AWG.
7. Neutral—white; "hot"—black.
8. Thin-wall and rigid.
9. A locknut and a bushing.
10 On exposed conduit runs.
11. Expansion or anchor bolts.
12. To remove the burrs which would otherwise damage the insulation of the wires when they are pulled through.
13. A tool used to bend conduit.
14 Ninety, saddle, and off-set.
15. The fixture stud.
16. Forty-eight inches.
17. Four.
18. Fish tape or "snake."
19. Armored cable (BX) and nonmetallic sheathed cable (Romex).
20. Between the wall switch and the ceiling outlet box.

CHAPTER 12
TELEPHONE COMMUNICATIONS

1. Receiver, transmitter, signalling device, source of energy (battery), and wires between the subsets.
2. Decreases the resistance.
3. Magnet, coil, and diaphragm.
4. Transformer.
5. To boost the talking voltage in the wires and thereby cut down transmission loss due to wire resistance.
6. It closes the battery circuit.
7. 90 volts, 20 cycles.
8. Alternating current.
9. Plug.
10. Allows the operator to talk to the subscriber; allows the operator to ring the subscriber; and allows the two subscribers to have uninterrupted conversation.

11. Series.
12. Alternating current.
13. At the switchboard or central office.
14. To prevent the direct current from flowing through the ringer.
15. PBX.
16. Distributing frames.
17. Heat coils, fuses, and lightning arresters.
18. It is a momentary break in the flow of d.c. current in the line.

CHAPTER 13

TELEPHONE-LINE CONSTRUCTION

1. Field wire.
2. Reeling out the wires, raising the wires to the crossarms, tensioning the wires, and tying the wires in.
3. Paper.
4. The suspension strand from which the aerial cable is suspended.
5. Strand puller or "come along."
6. Cable rings and lashing.
7. A rope mat.
8. A lashing machine (cable spinner), or by hand.
9. Terminal boxes.
10. Below.
11. Direct burial or in conduit.
12. Dig the trench; lay the conduit; build manholes; refill the trench; and pull in the cable.
13. Vitrified clay and asbestos-cement.
14. Rodding tool.
15. The top.

CHAPTER 14

INSTALLING THE TELEPHONE

1. Central office, outside plant, and the inside plant.
2. The drop wire.
3. At the terminal box or open wire, and at the protector.
4. Two wires.
5. The protective device and the connecting block.
6. The terminating point for the inside house wire and connection point for the subset.

7. Directly to the open wire.
8. To the binding posts of the terminal box.
9. Alongside the binding posts in the terminal box.
10. A wire support.
11. The drop wire clamp.
12. Two.
13. Drop wire-tip and ring, ground wire, and inside house wire-tip and ring.
14. Combined hand telephone set.
15. 56½ inches.
16. When the desk is more than 8 inches from the bulkhead.
17. To determine that the phone is connected to the proper pair, to check the ringing circuit, and to check the voice transmission to be sure it is loud and clear.
18. Tracer wire.
19. The positive side.
20. Tip and ring.
21. A low voltage source (batteries or transformer), a pushbutton, a bell or buzzer, and wire connecting them together.
22. No. 18.

CHAPTER 15

GROUNDS, SHORTS, AND OPEN CIRCUITS

1. The polarity of the meter terminals should match the polarity of the circuit.
2. In series.
3. A magneto generator.
4. By looping the conductor around the hook of the hook-on-volt-ammeter.
5. Heats up slowly and then burns out.
6. Make a quick visual check.
7. 220 volts.
8. A ground.
9. Always "kill" the circuit.
10. The center of the circuit.
11. Faulty insulation.
12. No output voltage.
13. Test telephone.

14. A "click" will be heard.
15. It will burn continuously.
16. Open.
17. No "click."

APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING CONSTRUCTION ELECTRICIAN'S MATES (CE)

RATING CODE NO. 630

SCOPE

GENERAL SERVICE RATING.

Construction electrician's mates install, operate, maintain, and repair electrical generating equipment, distribution systems (primary and secondary), transformers, switchboards, distribution panels, motors, inside wiring in buildings, and lighting fixtures. Erect poles, attach insulators, string wires, and lay cable for high tension power lines and communications lines. Maintain and repair all types of electrical equipment found at advanced bases. Install, operate, maintain, and repair communication equipment, PBX exchanges, switchboards, telephones, public address systems, inter-office communications systems, fire alarm systems, and portable radio equipment found at advanced bases.

EMERGENCY SERVICE RATINGS

Titles	Abbr.	Rating Code No.	Definition
Construction Electrician's Mates G	CEG	631	Work on ground and in shop on all types of electrical installations.
Construction Electrician's Mates P	CEP	632	Work aloft or aground on high tension systems.
Construction Electrician's Mates L	CEL	633	Work aloft or aground on communications systems.

NAVAL JOB CLASSIFICATIONS

Group		General Service	Emergency Service		
Code Numbers	Group Titles	CE	CEG	CEP	CEL
38100-38199	Electricians, Interior Communications	X			X
38300-38399	Electricians, Power and Lighting	X	X		
38400-38499	Electricians, Public Works	X	X	X	X
38900-38999	Electricians, Basic	X	X	X	X
48400-48499	Stationary Engineers and Firemen	X	X	X	

XXX .100 PRACTICAL FACTORS.

	Applicable Rates			
	CE 630	CEG 631	CEP 632	CEL 633
.101 TOOLS				
Use common electrical and communications hand tools.	3,2,1,C	3,2,1,C	3,2,1,C	3,2,1,C
Use power-driven tools (grinders, drills, etc.) in performance of electrical and communications work.	3,2,1,C	3,2,1,C	3,2,1,C	3,2,1,C
Operate lathes to turn down commutators on armatures.	1,C	1,C		
.102 Instrument Reading.				
Use properly a voltmeter, ammeter, and ohmmeter in checking and testing circuits and equipment.	3,2,1,C	3,2,1,C	3,2,1,C	3,2,1,C
.103 Blueprints				
Read communications and electrical blueprints.	3,2,1,C	3,2,1,C	3,2,1,C	3,2,1,C
Read and work from blueprints and wiring diagrams.	2,1,C	2,1,C	2,1,C	2,1,C
.104 Materials				
Identify commonly used:				
Electrical materials.	3,2,1,C	3,2,1,C	3,2,1,C	
Communications materials.	3,2,1,C			3,2,1,C
.105 Soldering and Brazing				
Perform soldering and brazing.	3,2,1,C	3,2,1,C	3,2,1,C	3,2,1,C
.106 Batteries				
Install, repair, and charge storage batteries. Install and check dry cell batteries.	3,2,1,C	3,2,1,C		3,2,1,C
.107 Motors				
Start, stop, clean, and lubricate electrical motors.	3,2,1,C	3,2,1,C	3,2,1,C	3,2,1,C
Make minor repairs to electrical motors.	2,1,C	2,1,C		
Assist in winding, insulating, and baking armatures and field coils.	2,1,C	2,1,C		
Wind, bake, and insulate armature and field coils for electrical motors.	1,C	1,C		
.108 Generators				
Operate, service, maintain, record data on, and stand watch on advanced base generating equipment.	3,2,1,C	3,2,1,C	3,2,1,C	3,2,1,C
Assist in servicing, lubricating, checking, and repairing generating equipment.	3,2,1,C	3,2,1,C	3,2,1,C	
Service, lubricate, check, and perform upkeep on generating equipment.	2,1,C	2,1,C	3,1,C	
Install, operate, and synchronize generators in parallel.	1,C	2,1,C	2,1,C	
Repair generator equipment. Stand watch in control room of a power house.	1,C	1,C	1,C	

	Applicable Rates			
	CE	CEG	CEP	CEL
.109 Wiring and Installations				
Splice, install, and pull wire through conduit. Install electrical fixtures, and assist in installing, maintaining, and repairing secondary electrical systems in a building. Bend and install conduit as required.	3,2,1,C	3,2,1,C	3,2,1,C	
Lay out and install any secondary electrical system.	1,C	1,C		
.110 Distribution				
Assist from ground or aloft in erecting poles, attaching cross arms, installing insulators, lightning arrestors, etc., in:				
High tension lines.	3,2,1,C		3,2,1,C	
Communications lines.	3,2,1,C			3,2,1,C
String and erect poles, attach cross arms, install insulators, lightning arrestors, etc., for:				
High tension lines.	2,1,C		2,1,C	
Communications lines.	2,1,C			2,1,C
Install the following:				
High tension wires aloft.	1,C		1,C	
Underground electrical systems.	1,C	1,C	1,C	
Communications systems aloft, underground, or underwater.	1,C			1,C
Splice and lay underground cable. Install transformers, boxes, distribution panels etc., on the ground.	2,1,C	2,1,C	2,1,C	
String communications lines aloft, erect poles, complete cross arms, terminate cans, etc. Lay underground telephone cable.	2,1,C			2,1,C
.111 Communications				
Install, maintain, and repair the following:				
Public address systems.	1,C			1,C
Inter-office systems.	1,C			1,C
Fire alarm systems.	1,C			1,C
Advanced base portable radio equipment.	C			C
.112 Telephone Installation				
Assist in installing, maintaining, and repairing telephone boxes, inside wiring, and bell and buzzer circuits.	2,1,C			3,2,1,C
Install, maintain, and repair telephone switchboards.	1,C			1,C
Install PBX communication systems.	1,C			1,C
Lay out and install telephone systems overhead, underground, or underwater from plans and specifications.	1,C			1,C
Direct men engaged in setting poles, stringing wire, or laying cable.	1,C			1,C

	Applicable Rates			
	CE	CEG	CEP	CEL
.113 Transformers				
Install, maintain, and repair current and voltage transformers (if available).	1,C	1,C	1,C	1,C
.114 Maintenance and Repair				
Locate and repair common failures to electrical systems, such as grounds, short circuits, and open circuits.	3,2,1,C	3,2,1,C		
Locate and repair common failures to communications systems, such as grounds, short circuits, faulty telephone boxes, etc.	1,C			2,1,C
Maintain and repair the following:				
High tension lines.	1,C		1,C	
Electrical motors and generators.	1,C	1,C		
Electrical equipment, relays, solenoids, switches.	1,C			1,C
.115 Inspection				
Check electrical systems or communications systems for conformity with specifications and plans.	2,1,C	2,1,C	2,1,C	2,1,C
.116 Trouble-Shooting				
Diagnose, analyze, and prescribe remedies for:				
Electrical failures.	1,C	1,C	1,C	
Communications failures.	1,C			1,C
.117 Estimates				
Estimate and make quantity surveys from plans, sketches, and specifications.	1,C	1,C	1,C	1,C
.118 First Aid				
Simulate the rescue of a person in contact with an energized circuit. Resuscitate a person unconscious from shock (simulated condition). Simulate treatment for shock and burns.	3,2,1,C	3,2,1,C	3,2,1,C	3,2,1,C
.119 Safety Precautions				
Safety precautions to be observed in the installation, operation, and maintenance of electrical equipment, high tension wires, and power equipment.	3,2,1,C	3,2,1,C	3,2,1,C	3,2,1,C
.120 Records and Reports				
Prepare requisitions for materials or equipment.	C	C	C	C
Prepare neat and accurate operational reports.	C	C	C	C
.121 Publications				
Use electrical and communications handbooks to select materials and to obtain technical data.	1,C	1,C	1,C	1,C

	Applicable Rates			
	CE	CEG	CEP	CEL
.122 Supervision				
Supervise and train personnel engaged in the installation, maintenance, operation, and repair of:				
Communications systems.	C	C		C
High tension systems.	C		C	
Other electrical systems.	C	C		
Organize and administer an electrical repair shop.	C	C		
XXX .200 EXAMINATION SUBJECTS				
.201 Nomenclature				
Tools, symbols, materials, methods, and equipment common to:				
Electrical work	3,2,1,C	3,2,1,C	3,2,1,C	
Communications work.	3,2,1,C			3,2,1,C
.202 Blueprints				
Wiring diagrams and schematics of starting apparatus, electrical instruments, and other electrical equipment.	2,1,C	2,1,C	2,1,C	2,1,C
.203 Theory				
Direct current theory, Ohm's law, Kirchhoff's laws. Solve problems in direct current.	3,2,1,C	3,2,1,C	3,2,1,C	3,2,1,C
Alternating current theory. Solve simple problems in alternating current.	2,1,C	2,1,C	2,1,C	2,1,C
Compute the elements of electrical circuits for A.C. and D.C.	1,C	1,C	1,C	
Theory and practical aspects of inductance, frequency, capacitance, wave length, vacuum tubes, etc., as applied to communications.	1,C	1,C	1,C	3,2,1,C
.204 Motors and Generators				
Characteristics and uses of D.C. motors.	2,1,C	2,1,C	2,1,C	2,1,C
Construction, characteristics, and uses of A.C. and D. C. generating equipment found at advanced bases.	2,1,C	2,1,C	2,1,C	2,1,C
Construction, characteristics, and uses of A.C. and D.C. motors found at advanced bases.	1,C	1,C	1,C	1,C
.205 PBX Systems				
Operation of PBX telephone systems.	3,2,1,C			3,2,1,C
Principles of PBX, including dial telephone systems.	2,1,C			2,1,C
.206 Multi-Phase Hookups				
Advantages, characteristics, and uses of Y, Delta, and V connections for transformers, and of three- and four-wire transmission systems.	1,C	1,C	2,1,C	

	Applicable Rates			
	CE	CEG	CEP	CEL
.207 Load Conditions				
Relationship between load, generator capacity, wire, switch, and transformer sizes.	1,C	1,C	1,C	1,C
.208 First Aid				
First aid, with emphasis on the treatment of electric shock and acid burns.	3,2,1,C	3,2,1,C	3,2,1,C	3,2,1,C
.209 Safety Precautions				
Safety precautions to be observed in the installation, operation, and maintenance of the following:				
Generators and power equipment.	3,2,1,C	3,2,1,C	3,2,1,C	
Electrical apparatus.	3,2,1,C	3,2,1,C	3,2,1,C	
Communications apparatus.	3,2,1,C			3,2,1,C
Safety precautions to be observed in the following:				
Climbing poles, buildings, or towers to string or work on wires.	2,1,C		2,1,C	2,1 C
Working with high tension electrical systems.	3,2,1,C	3,2,1,C	3,2,1,C	
Safety standards and safety measures applicable to:				
High tension electrical systems.	C	C	C	
Generating or power house equipment.	C	C	C	
Secondary electrical systems.	C	C		
Communications installations.	C			C
.210 Publications				
Use of handbooks and other technical data.	1,C	1,C	1,C	1,C
.211 Organization				
Organization of the activity to which attached and the relationship of other ratings to electrical or communications work.	1,C	1,C	1,C	1,C

XXX .300 NORMAL PATH OF ADVANCEMENT TO WARRANT GRADE

Construction electrician's mates advance to Warrant ELECTRICIAN 7591 (*Construction Electrician*), and act as Assistant Electrical Engineers in charge of design and construction of electrical installations for advanced bases.

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